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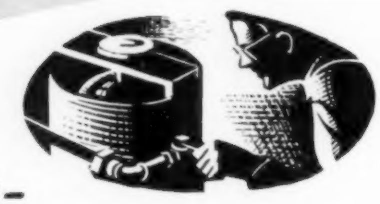
Cover: Strain Gage, by Byrle Benthien

RYERSON ALLOY STEEL REPORTS

...take guesswork out of heat treating

with this –

The exact chemical content of each heat of steel is determined by laboratory tests.



and this –

Jominy End-Quench Test interpretation gives accurate heat treatment response data.

and this –

Tensile strength tests are used to double check the exact physicals attainable with this alloy.

and this –

Each bar of steel is identified with stamped heat symbols and painted color marks.

and again –

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RYERSON STEEL

Developments in Gray Iron and Malleable

By G. Vennerholm
Ford Motor Co., Dearborn, Mich.

AN analysis of wartime developments in the foundry industry cannot be entirely confined to the wartime emergency, but must, in many branches, cover a longer period of time. Many of the developments which have formed such a vital part in the success of our armament program constitute an evolution of methods and theories known to the foundrymen in the past but utilized only to a limited extent — or not applied at all.

With the outbreak of war in 1941, it soon became evident that a critical shortage of manufacturing facilities in many fields of industry, and particularly in the forging industry, would seriously retard the production of implements of war unless a rapid solution could be found. It was only natural that the minds of many engineers and designers turned to the foundries in the hope of solving the problems through the use of castings rather than forged or wrought assemblies.

I believe it can safely be said that the foundry industry in general has done an outstanding job in handling their many difficult assignments in the past five years, and that this is best evidenced by the great variety of parts formerly made by other methods of manufacture which were converted to castings. It is my intention to review some of the progress made in the gray iron, malleable, and steel casting industry, directly or indirectly as a result of the war effort, and discuss some of the metallurgical and other developments which underlie this progress.

Gray Iron

Judged by the output in tons, the gray iron foundry forms the largest branch of the ferrous casting industry. This in itself indicates the vital part gray iron played in war. When it is furthermore realized that not many years ago an iron of about 40,000 psi. was considered a high-test iron, whereas today considerable tonnages are produced testing as high as 70,000 and 80,000 psi. in tension, it is evident that its usefulness as an engineering material has been greatly increased.

The extensive metallurgical research during the last few years has also helped to remove some of the prejudice against gray iron. It has frequently been termed "weak", "brittle", and "unreliable" by many engineers who do not seem to realize that gray iron is one of the most complex metallurgical alloys, capable of a wide variety of forms, and a very important engineering material with an extensive field of utilization for highly stressed parts.

Melting Practice — Although electric and other furnaces have found considerable application in the gray iron foundry, the cupola still remains the all-important melting unit. Extensive studies of cupola operation have resulted in greatly improved metallurgical control and a better understanding of the detrimental effect on the iron of certain products of combustion. It has been found, in particular, that excessive amounts of hydrogen when present in the structure of iron have a pronounced embrittling effect; hydrogen increases the carbide stability, tends to produce chill spots, and to promote porosity. When moisture enters the cupola with the air and immediately strikes the white hot coke it is decomposed into hydrogen and oxygen. This absorbs heat — has a chilling effect. Likewise the hydrogen, being mainly in the nascent state, is exceedingly active in its action on the hot iron it meets. An interesting illustration of the effect of hydrogen in gray iron is shown in Table I on the next page, quoted from a research carried out by J. E. Hurst in England and reported in *Metallurgia* for December 1944.

It may be of interest to see what seemingly insignificant fluctuations in humidity actually amount to under extreme conditions. On a cold,

Table I — Gases in Silicon-Iron Alloys (Hurst)

Condition of Iron	Oxygen★	Nitrogen★	Hydrogen†
Sound	0.0009	0.0037	1.40
Sound	0.0010	0.0034	1.71
Sound	0.0008	0.0028	1.94
Sound	0.0011	0.0036	1.96
Porous	0.0100	0.0040	6.99
More porous	0.0190	0.0042	10.08
Very porous	0.0110	0.0027	5.05
Very porous	0.0117	0.0041	10.5

★Weight %. †Cc. per 100 g. metal.

dry day, with the temperature 30° F. and 30% relative humidity, the air contains 0.8 grain of water per cu.ft. Compare this with 14.4 grains on a warm, moist day, with the temperature 90° F. and 90% relative humidity. For a 90-in. cupola requiring 9650 cu.ft. of air per min., we find that 7¼ gal. of water enter the cupola with the blast every hour in the first instance, whereas this figure increases to 160 gal. per hr. in the second instance — a potent factor on the quality of the iron indeed, which is too often neglected.

The careful foundry metallurgist will offset this condition as well as he can by increasing the coke charge as the absolute humidity rises. This procedure requires constant attention and eliminates only part of the trouble. The temperature is maintained but the hydrogen is still there. The most satisfactory solution has been found by moisture control units. There are today a number of these controls in several foundries; the results indicate that an important advance has been made. Rather than to eliminate the moisture entirely, most of these units control it at a definite level, usually 3 grains per cu.ft., with resultant uniformity of operation.

Basic Cupola — In addition to moisture control units in the iron foundry, a development of considerable interest and promise is the basic lined cupola. Here we have an idea which is by no means new but only during the last couple of years has it been put to practical application — mainly through the work carried out by E. S. Renshaw of the Ford Motor Co. in England. The primary object is to have melting equipment in which the phosphorus and sulphur can be reduced prior to charging hot metal into bessemer converters for manufacture of steel castings, but a number of applications in the gray iron foundry have also been found. Use of a basic cupola will reduce the 0.12% phosphorus and the 0.07% sulphur (normal for gray iron) down to 0.03 max. for each element.

Inoculants — The most far reaching advance in gray iron metallurgy in recent years has been accomplished by means of so-called inoculants. These inoculants as used in foundry metallurgy apply to various types of graphitizers or stabilizers or combinations of both. They are usually added to the stream of metal from furnace to pouring ladle.

In order to understand the effect of these inoculants on the iron and the great increase in uniformity, strength, and soundness which has been accomplished through the extensive research which underlies these seemingly simple additions, let us consider a few fundamental facts.

In normal gray iron, the structure is composed of pearlite, randomly distributed graphite, and free ferrite. The amount of the ferrite and the size of the graphite flakes depend upon the carbon and silicon in the alloy. Frequently, however, the graphite occurs in very fine form arranged in a dendritic pattern (identified by a coarse or dendritic, irregular, dark colored fracture) whereas the normal iron generally has a rather light gray and smooth fracture. This dendritic distribution invariably lowers the strength of the iron due to the continuous nature of the graphite pattern. It also results in a part with poor wear resistance. Such irons, furthermore, are subject to chilling, since the carbides graphitize at a slower rate, and hence persist as hard substances. Frequently the two structures — graphitized and white iron — occur in one and the same casting and are of identical analyses.

Table II — Gray Irons Before and After Inoculating With Nickel and Silicon (International Nickel Co. Data)

	Medium Carbon (3%)		Low Carbon (2¼%)	
	Plain	Inoculated	Plain	Inoculated
Tensile strength	39,700 psi.	43,600 psi.	38,000 psi.	60,000 psi.
Transverse load	2,520 lb.	3,160 lb.	3,240 lb.	5,170 lb.
Deflection	0.253 in.★	0.381 in.★	0.078 in.†	0.156 in.†
Izod impact	22 ft-lb.	38 ft-lb.	17 ft-lb.	31 ft-lb.

★18-in. span. †12-in. span.

The tendency to form dendritic graphite patterns rather than random flake graphite is increased as the carbon content decreases, and it can therefore be readily seen that the problems have been multiplied with the development of the modern high strength irons which ordinarily have comparatively low carbon.

Conclusive proof of the manner of formation of the different types of graphite has not been

given but evidence indicates, as pointed out by John T. Eash in his paper* on "The Effect of Ladle Inoculation on the Solidification of Gray Cast Iron", that the random type of graphite separates from the liquid during the freezing of the eutectic mixture, whereas the graphite arranged in a dendritic pattern occurs in irons which solidify in the metastable iron-carbon system as white iron, and the eutectic carbide, formed during solidification, subsequently decomposes in the solid state to form iron and graphite.

The effect of the inoculants of the graphitizing group (which consist of strong graphitizers such as Si-Ca-Ti alloys, Si-Ni alloys, or silicon carbide) is to produce fine graphite nuclei in the molten metal which promote the formation of the random type graphite. Due to the large number of nuclei formed, the graphite flakes are of moderate size and are of uniform distribution. In comparison with irons with coarse graphite flakes, fine graphite increases the tensile strength as well as transverse deflection without appreciably increasing the hardness. Freedom from dendritic type of graphite, furthermore, increases the resistance to wear. As shrinkage is a direct function of percentage of combined carbon, the effect of the inoculants in reducing the chilling tendency also results in increased soundness and uniformity of structure (and hardness) — all of which are of particular importance in castings with varying cross sections.

*Presented before a gray iron session at the American Foundrymen's Association convention (New York City) May 14, 1941.

The increased use of alloying elements in modern high strength irons, such as chromium, molybdenum and similar carbide formers, has not only increased the need for graphitizing inoculants but has also resulted in the development of so-called stabilizing inoculants. The latter are alloys of chromium, silicon, manganese, molybdenum and titanium, in various combinations; by using them, alloy additions can be made to a base iron without the difficulties encountered when the same are added as ferro-alloys.

The effect of inoculants in improving physical properties is best evidenced by Table II which contains results obtained by International Nickel Co. on a medium carbon (slightly over 3% carbon) and a low carbon (about 2.25% carbon) iron by adding about 0.70% nickel and 0.35% silicon in the form of a nickel-silicon inoculant.

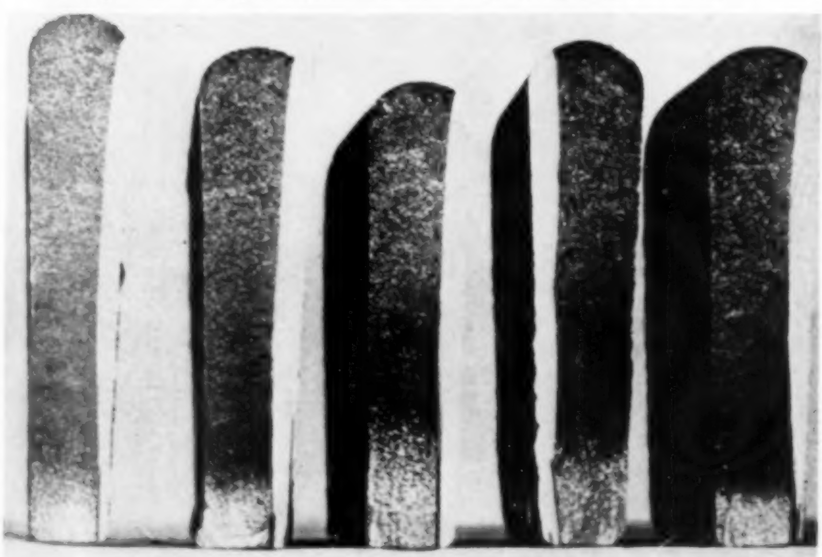
Figure 1 indicates further the effect of inoculants in combination with alloys in obtaining high physical properties without increasing chill.

Mold Atmosphere — Extensive research has been carried out during the last few years on the effect of gases in the mold or generated in the mold on the penetration of surface defects. The cause of these defects appears to be twofold. The simpler of the two — generally called "metal penetration" — is caused by infiltration of molten metal into the surface of the mold or core, tightly binding a thin layer of sand to the casting. Porous areas of the mold or soft ramming is responsible; a correction of the sand mix or molding technique will usually suffice to cure "metal penetration".

A different type of penetration, which frequently is of greater magnitude, is caused by the effect of mold gases on the metal. Particularly oxygen, through the formation of low melting oxides which flux the surface of the mold, causes a layer of sand, iron oxide, and metal to fuse to the casting. This condition wastes many man-hours in the cleaning room. Mold washes such as silica wash or graphite wash, although sometimes beneficial, frequently do not eliminate this condition.

The effect of mold gases has been studied by H. Taylor, of the Naval Research Laboratory, and by H. W. Dietert and his collaborators in Detroit. The work is of particular interest because of the very

Fig. 1 — Strong Inoculated Irons Without Increased Chill



80,500	74,100	82,280	85,800	55,000	Tensile strength
331	302	321	302	429	Brinell hardness
2.49%	2.50%	2.50%	2.55%	2.83%	Total carbon
2.71	2.80	2.73	2.70	3.07	Silicon

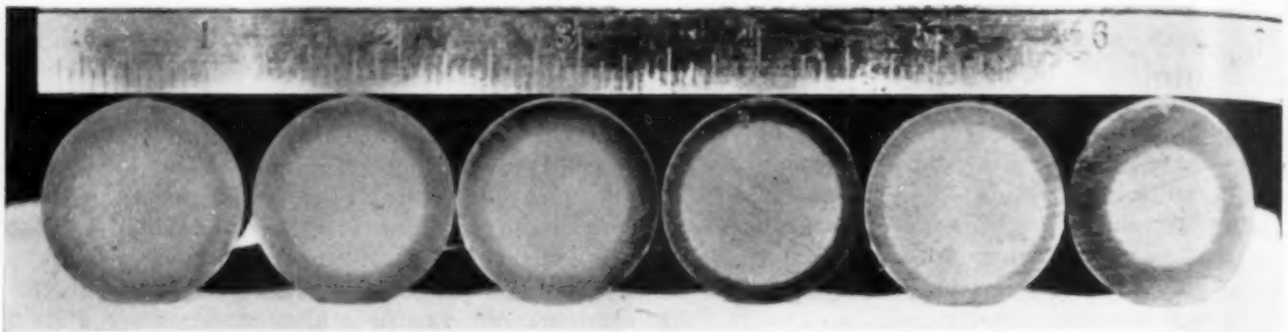


Fig. 2 — Fracture of Representative Flame Hardened Cast Iron Rounds. Note uniformity of penetration

ingenious method they adopted to study this effect. They inserted steel pins into small, holed-out cores, and then heated the assembly to various temperatures in different atmospheres. It was found that when heated in oxygen for a relatively short period of time at as low a temperature as 1700° F., the pins migrated completely into the sand by the formation of low melting oxides. When the oxygen was replaced by nitrogen or other inert gas, no penetration occurred.

The effect of additions to the sand of different chemicals and materials, such as wood charcoal, starch, urea, boric anhydride, or ascarite, in preventing the deleterious effect of the mold gases, was also studied. As a result of these and similar investigations new molding materials are already appearing on the market. These, with new molding methods, will go a long way toward solving the time-consuming and costly defect of "metal penetration" in gray iron founding.

Heat Treatment — Although heat treatment of gray iron is by no means a new thing, by far the major portion of the output is used in the as-cast condition. Considerable progress has been made in the last few years and new heat treating methods have been developed for particular applications. Perhaps the most interesting example is the utilization of high frequency induction for hardening the internal surfaces of cast iron cylinder liners for heavy duty gas engines.

Flame hardening of cast iron has also found widespread application, particularly in connection with camshafts and similar items where localized hardening is required to resist wear. Figure 2 shows some fractures of various types of flame hardened irons, and it will be observed that depth is uniform, and can be held under control — shallow or deep — as desired. (In connection with camshafts, it may be of interest to show a fracture through the cam of a Ford camshaft — Fig. 3 — where the required wear resistance is obtained through careful metallurgical control without subsequent heat treatment.)

The application of isothermal heat treat methods for improving the physical properties of cast iron has been given considerable attention with promising results. Of particular interest in this respect is the work by E. L. Bartholomew of United Shoe Machinery Co.

Space does not permit further discussion of the many additional developments and improvements which, together with extensive modernization and mechanization throughout the gray iron industry, have made possible the large contribution of cast iron to modern engineering industry. Before closing, a few remarks are in order about some iron castings which are striking illustrations of the technical advances made as a result of wartime necessities.

Cast Iron Crankshafts — Perhaps the most outstanding of these is the manufacture of large diesel engine crankshafts for submarines and cargo ships

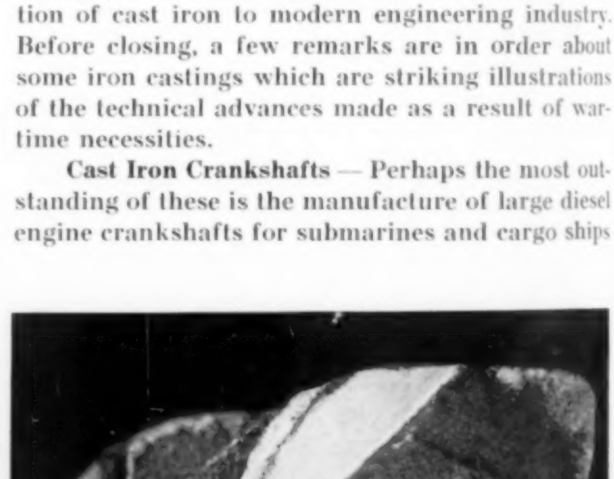


Fig. 3 — Fracture of Ford Cast Iron Camshaft. Differentially hardened surface obtained by control of molding and metallurgy; no subsequent heat treatment necessary

and landing craft. These crankshafts have not only set up an excellent record for service, but have also eliminated one of the most serious bottlenecks that existed because of lack of forging capacity.

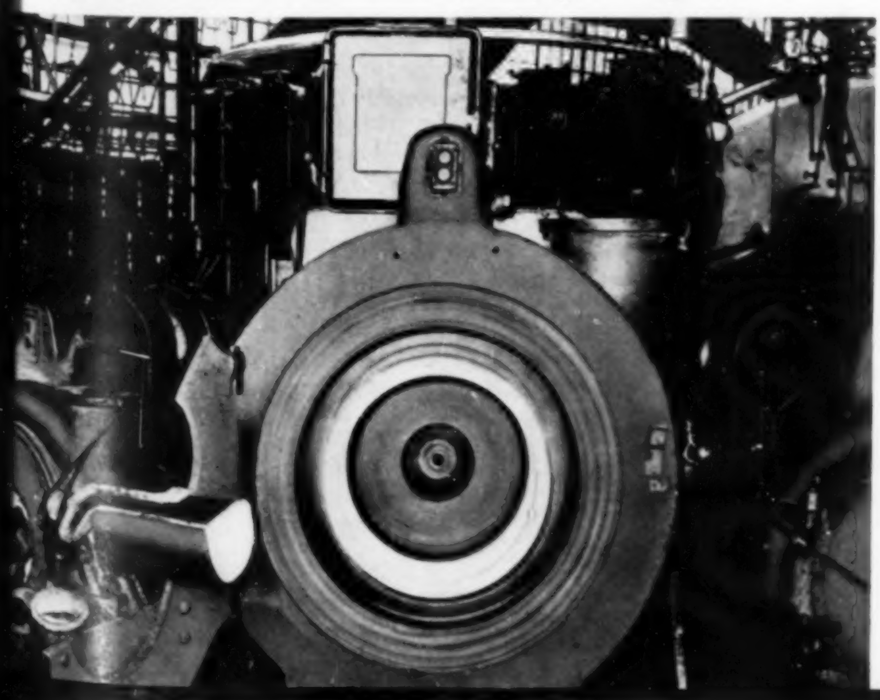
Great savings in material and machining have also been effected, which is best evidenced by comparing the block forged crankshaft for an eight-cylinder marine diesel engine which weighed 36,000 lb. in the rough and 12,000 finished machined, with the casting used in place of it which weighs only 14,000 lb. in the rough — a substantial saving in both critical material and machining time. Some test results of crankshaft iron cast by Campbell, Wyant and Cannon Foundry

Table III — Alloy Iron for Large Diesel Crankshafts

Tests on 2½-In. Bar	Center	Surface
Transverse tests		
Span	18 in.	18 in.
Diameter	1.25 in.	1.25 in.
Load	5,900 lb.	5,410 lb.
Deflection	0.494 in.	0.429 in.
Tensile strength	72,700 psi.	78,200 psi.
Modulus	19,000,000	
Compressive strength	203,000 psi.	215,400 psi.
Shear strength	86,000 psi.	89,800 psi.
Modulus	6,530,000	7,030,000
Brinell hardness	288	292

Co. are shown in Table III. The specimens were taken from bars cast 2½ in. round by 36 in. long. Note particularly the high figures for deflection — nearly ½ in. Analysis was 2.65% total carbon, 2.48% silicon, 1.18% manganese, 1.21% nickel, 0.17% chromium and 1.15% molybdenum.

Fig. 4 — Centrifugal Machine — Pouring Spout Swung to Left — for Airplane Brake Drums. (Centrifugal Fusing Co.)



Centrifugal Brake Drums — In the early stage of the war, most of the brake drums for our bombers were made of steel, but it was found that after as few as 10 to 20 stops, the heat generated would cause a contraction in the drum to the point where it had to be removed to free the lining and reground. Brake drum material requires also a good resistance to heat checking as well as galling and frictional wear. The solution in this case was found through the application of the so-called centrifuge method, used for manufacturing automotive drums prior to the war, which consists of inserting a corrugated and flanged steel shell (fluxed and preheated to 1200 to 1400° F.) into a centrifugal spinning machine and pouring alloy iron into the center. Metal-to-metal fusion makes a unit which combines the supporting toughness and strength of steel with the heat and wear resistance of the alloy cast iron.

Figure 4 shows the casting machine, with pouring spout swung aside to the left. The iron analyzes about 3.75% carbon, 0.60% manganese, 1.50% silicon, 1.50% nickel, 0.35% chromium and 0.35% manganese. The high total carbon is well distributed to provide resistance to heat checking; the silicon is low to furnish high resistance to distortion. This combination of cast iron fused to steel eliminated the early difficulties to the extent that 300 to 400 stops per drum are possible with a large bomber; the wear, heat checking and cracking of the drum are reduced to a minimum.

Malleable Iron

The malleable industry, which in 1944 produced something over a million tons of castings, has also made rapid advances both through metallurgical research and through extensive mechanization and modernization in both old and new facilities.

A considerable increase has come from duplex melting processes, such as the combination of cupola and air furnace, or cupola and electric furnace, where the metal is melted in the cupola and then refined in these holding furnaces. Increased uniformity and better control have both been accomplished thereby.

The metallurgical trend in the malleable industry has been toward much lower carbon content. This improves the physical properties and opens a

much wider field of application — best evidenced by the very large malleable castings used in mechanized ordnance in heavy rear axle housings for trucks, and gun bases weighing 300 to 400 lb. and having sections as much as 4 in. thick. These have been successfully manufactured in large quantities. Figure 5 illustrates the size of some of these new castings, as compared with the typical prewar castings at either end of the line-up.

The trend for the "normal" irons for typical light section work has also been toward a somewhat lower carbon and higher silicon. This has decreased the annealing time required. A typical analysis will run about 2.4% carbon and about 1.4% silicon, allowing a successful annealing operation in 25 to 30 hr.

Fig. 5 — Malleable Castings of Wartime, Compared in Size With "Large" Peacetime Castings Placed at Either End

Of considerable interest metallurgically is the effect of tellurium and various other addition agents as carbide stabilizers in connection with castings of large cross section. In a typical iron for this type of work containing 2.25% carbon and 1.15% silicon, about 1 g. of tellurium is added per 100 lb. of metal.

The addition of boron to malleable iron has also been investigated — in particular by Harry A. Schwartz — and it was found that this element offsets the stabilizing effect of the carbide-formers such as chromium to the extent that 0.001% boron will neutralize approximately 0.10% chromium. With the rapidly deteriorating quality of scrap this effect of boron is of considerable importance.

Some interesting research has been reported by Battelle Memorial Institute and others relative to the effect of hydrogen upon the graphitization of malleable iron. It has been shown that a short preheat at approximately 600° F. for 6 or 7 hr. successfully removes the hydrogen. This has a pronounced effect in increasing the number of nucleation centers, resulting in much finer temper carbon particles, more evenly distributed. These findings have already been put into practice; pretreatments of this type are now included in the standard malleableizing cycles in a number of progressive foundries.

The outstanding development in the heat treatment of malleable iron has been the introduction of annealing ovens with controlled atmosphere, heated with radiant tubes. Such equipment has greatly shortened the annealing cycle by eliminating the old method of packing the castings in boxes. Uniformity is also improved.

Special types of malleable irons, such as pearlitic malleable, offered on the market under various trade names, have found widespread use as substitutes for steel castings as well as forgings.

An interesting development, which has now been applied on a large production volume by Ford Motor Co., is a high carbon, high silicon steel. By varying the heat treatment this will produce structures ranging from finely spheroidized pearlite to a completely annealed matrix composed of ferrite and temper carbon. This new cast alloy is particularly valuable because of its excellent physical properties. Its extensive field of application has been further increased by the use of inoculants as described under gray iron. Typical physical properties are:

	Spheroidized	Graphitized (Inoculated)
Yield strength	68,000 psi.	45,000 psi.
Tensile strength	105,000	65,000
Elongation	18%	29%
Reduction of area	22%	40%
Brinell hardness	212	141

Ac, Ar, Ae

A Review of the Steel Standardization Group's Method for the Determination of Critical Points of Steel

By the Steel Standardization Group

SEVERAL YEARS AGO the Steel Standardization Group* published (*Metal Progress* for June 1942, page 822) the details of a precision method based on dilatometric methods for determining the critical points of commercial steels. It was postulated at that time that the logarithm of the rate of temperature change plotted against the temperature of the transformation point (be it Ac_1, Ac_3, Ar_1 or Ar_3) yielded a straight line relationship and that these straight lines, through the heating and cooling values for the same change point determined at several cooling rates, intersected at a close approximation of the true equilibrium temperature of the transformation. This assumption underlies the left portion of Fig. 2 (page 1170), reprinted from the 1942 article.

Since that time, continued use of this method by several of the cooperating laboratories has proved its value by accurately determining the critical points of a wide variety of steels. Furthermore, the validity of the above fundamental relationships has been demonstrated over a wide range of carbon and alloy contents, from plain carbon steels through many of the intermediate alloy grades and, with proper interpretation, to such notoriously sluggish analyses as S.A.E. 3335 and 4340.

In the intervening years the judgment of the Group has remained unchanged regarding the superiority of the dilatometric method over other commercial methods of critical point determinations. Thermal methods such as the recommended practice of A.S.T.M. E14-33, while equally practicable, do not yield as much information. A quenching series is perhaps more precise if run at sufficiently small temperature intervals, but is laborious and the acquisition of complete information is quite time-consuming. Measurement of electromotive force, of electrical resistance, and magnetic properties — all as functions of temperature — are capable of at least equal accuracy but require elaborate equipment and are not suitable for rapid determinations.

Additional knowledge gained from extensive

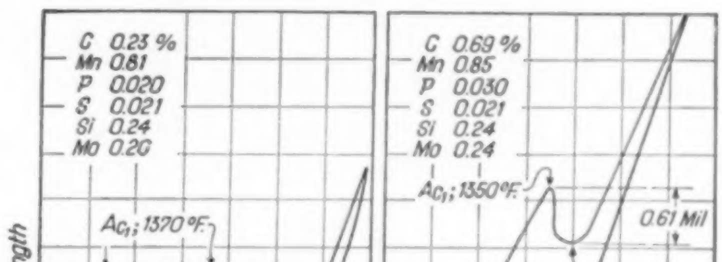


Fig. 1 — Dilation Vs. Temperature Curves for Two Carbon-Molybdenum Steels, Using the Standard Test Cycle and Temperature Change of 400° F. per Hr.

*An informal organization, described briefly in "Critical Points" for November 1941, of metallurgists for Bethlehem Steel Co., Carnegie-Illinois Steel Corp., Chrysler Corp., Great Lakes Steel Corp., Pittsburgh Crucible Steel Co., Republic Steel Corp., and The Timken Roller Bearing Co., Steel & Tube Division.

use of the dilatometric method has necessitated some revisions and additions to the method as originally published. The revised procedure as contained in the publication of the Steel Standardization Group entitled "Precision Methods of Steel Testing" follows.

The Dilatometric Test

1. Sample — The sample shall be a cylinder either encompassing the entire cross section of the ingot or taken in such a way that the exact chemistry of the sample is known. The sample shall be drilled to accommodate a thermocouple bead at its center. The length and diameter may be adjusted to suit the equipment but the specimen must be long enough to produce easily determined dilatations and of sufficient diameter to be rigid.

2. Heating — The furnace must be able to heat the sample uniformly over its entire length and to a maximum temperature variation of 10° F. The rate of temperature change must be rigidly and automatically controlled in order for results to be reproducible and of any meaning. The maximum temperature attained and the holding period at that temperature affect the Ar points, making it necessary to control these variables.

3. Test Cycle — The following test cycle is recommended:

(a) Heat to 100° F. below approximate Ac_1.
(b) Hold at this temperature 30 min., to approximate equilibrium conditions.
(c) Heat at chosen rate through Ac_3 plus 20° F.
(d) Heat rapidly to 150° F. above observed Ac_3.
(e) Cool rapidly to observed Ac_3 plus 20° F.
(f) Cool at chosen rate to Ar_1 minus 20° F.

4. Interpretation — The A_1 and A_3 critical points of steel are reversible changes of state and hence each should occur at a definite temperature under equilibrium conditions. Physical inertia or hysteresis, however, causes divergence in the observed point at appreciable rates of heating and cooling and this divergence increases with increase in rate of temperature change (see Fig. 2).

Figure 1 shows typical dilatometric curves and the method of selecting the critical points from the curve. It will be noted that the critical points are taken as the points at which the rate of change of specimen length with respect to temperature is zero. It is recognized that theoretically the critical points should be the first and last points at which a change in the slope of the curve is discernible. The method indicated is a convention generally used because the points of zero rate of change are more readily picked from the curve. The results of the conventional method are more nearly reproducible than results of the theoretically exact method. The critical points determined by the conventional method are deemed sufficiently accurate for most purposes.

In many cases it is necessary to know the critical points at different rates of temperature

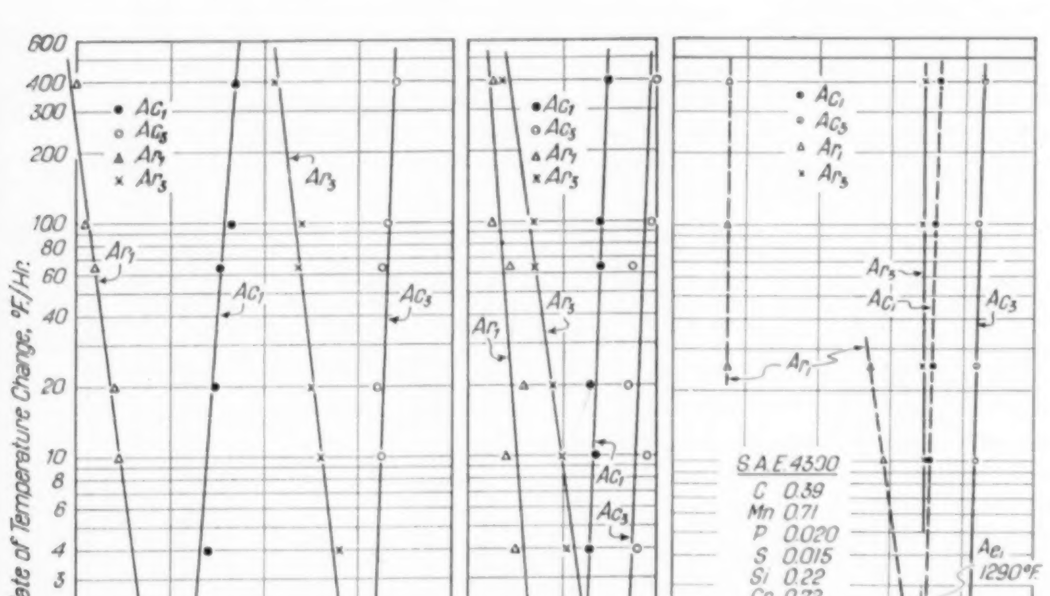


Fig. 2 — Semi-Logarithmic Charts Showing Critical Points of Three S.A.E. Steels as Determined at Different Rates of Temperature Change, and the Method of Extrapolation for an Approximate Equilibrium. At left are data for two low-alloy steels (carbon-molybdenum, S.A.E. 4000 series) and at right for steels like S.A.E. 4340 with "split" transformation on cooling at certain rates

change. For ordinary heat treating, the Ac_3 point at a rapid rate of heating is desired; for spheroidizing anneals, practically the equilibrium A_1 point is required; and for handling large sections, particularly of sluggish analyses, the Ar points at slow rates of cooling are very necessary information. The determination of critical points at rigidly controlled rates of temperature change of 400, 100 and 10° F. per hr. is recommended when complete information is desired.

5. Representation of Results — The critical point values obtained at various rates are best presented by plotting the logarithm of the rate of temperature change versus the temperature of the transformation and drawing the best straight line through the values at different rates for the same critical point. A typical example of this method of presentation is shown in Fig. 2. From such a plot the critical points at any desired rate of temperature change may be read directly. The point of intersection of the lines for the same transformation (that is, the Ac_1 and Ar_1) is a good approximation of its equilibrium transformation temperature. It is true that such curves should theoretically approach each other asymptotically at zero rate but if the straight lines intersect at or below 0.5° F. per hr., a straight line is deemed sufficiently accurate.

6. Precautions — Some precautions are necessary in applying this method of representation in those cases where the steel undergoes transformation in two temperature ranges over certain variations in cooling rate. Such split transformations are characteristic of the higher alloy steels in the range of cooling rates of commercial interest. Under such conditions the transformation of austenite to a pearlitic product is not complete in the time allotted by the cooling rate imposed and the balance of the austenite decomposes into bainite at a considerably lower range of temperature. It is, therefore, valid to use only the upper value of the two recorded transformation end points in the semi-log plot to determine the Ae_1 temperature. Furthermore, the end of the pearlite transformation is usually not distinct enough for satisfactory accuracy unless more than one-half of the austenite has decomposed by this time.

Comments

The principal addition to the text published in 1942 comprises the precautions involved in the interpretation of data for steels whose S-curve has a double loop. The right-hand portion of Fig. 2 illustrates this condition as applied to a sample of S.A.E. 4340. The Ar_1 transformation at rates of 25° F. per hr. and below only can be used in the graphical estimation of the Ae_1 temperature. At this and higher rates, bainite starts to form and is substantially complete only at much lower temperatures. The lack of variation of the bainite formation temperature with change in cooling rate is undoubtedly due to the flat character of the lower loop of the S-curve for this steel. (See "Atlas of Transformation Diagrams", U. S. Steel Corp., page 64, for S-curve of S.A.E. 4340.)

Bits and Pieces

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Soldered Versus Double-Seamed Closures

EFFORTS to conserve tin have followed several different courses. There was, for example, unlimited development in the field of low-tin solders. Brazing, soldering, and welding techniques were studied and changes made to effect economies in many instances. One development which proved of advantage, not alone from the standpoint of tin conservation but also because of resulting increase in manufacturing efficiency, has been the adaptation of a double-seamed closure on casings for capacitors.

Solder has been completely eliminated from the cover seam of capacitor units of a standard design by mechanically spinning the cover onto the body of the can. Billions of food cans have been closed by this method, and the use of automatic machinery to perform the operation on round or rectangular cans is an obvious manufacturing improvement. However, the successful application of double-seamed closures on capacitors was dependent on the selection of a proper

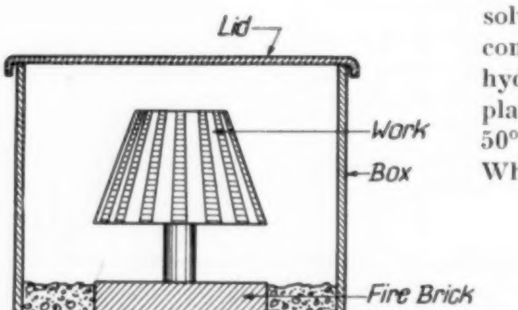
metal sealing adhesive which bonds together the cover and can body, for the completed capacitor is subjected to a heat treating cycle before the item is ready for shipment. Other vitally important properties of the metal cement are lack of contaminating effect on the liquid dielectric and permanent seal through the fluctuating temperature cycles encountered by the capacitor in use.

The fact that these divergent requirements have been successfully met, and in a commercial (cost-competitive) way, indicates that the possibilities of the so-called mechanical joints have not yet been adequately explored. (C. H. HANNON, Pittsfield works laboratory, General Electric Co.)

Hardening of High Speed Tools

A SUPERIOR method of hardening milling cutters, reamers and other tools made of high speed toolsteel, without benefit of atmosphere controlled (?) furnaces, has been used by Tube-Turns, Inc., for some time.

As shown in the sketch, we place the work on a piece of firebrick inside a lidded container and fill the container to the level of the brick with carbonaceous material such as charcoal or carburizing compound or a mixture of both. (Needless to say, the work should not come in contact with the compound, as a fusion into the metal would occur at the temperatures required.)



For high speed hardening the container should have a removable lid in order to reach work quickly when it is time to quench.

The standard procedure of high speed hardening may then be followed, allowing ample time for heat to soak through the container to the work. The carbon compound serves to neutralize the oxidizing atmosphere originally inside the container.

Typical results obtained on a standard 18-4-1 high speed steel treated in this manner were:

1. As quenched, surface hardness, C-64.
2. As quenched and ground 0.025 in., C-64.
3. After double draws of 2 hr., C-65.

A slight case may develop in some instances but is not detrimental for most applications. This method is believed to be superior to the messy, hit-or-miss practice of protective coatings for open furnace hardening. (THEODORE F. BURCH, die heat treating department, Tube-Turns, Inc.)

Ultrathin Nickel Ribbons

PRODUCTION of uniform nickel ribbons as thin as 0.1 micron (0.0001 mm. or 250,000 per in.) for bolometer* filaments has been satisfactorily done by electrolytic methods. First a suitable piece of copper foil about 0.002 in. thick was folded around the edge of a 6½ by 8-cm. copper plate and then immersed in the electrolyte, and connected as cathode. Nickel was deposited only on one face of the foil. The anode was "pure grade A nickel". The electrolyte was made of chemical reagents: $NiSO_4 \cdot 6H_2O$ 120 g. per liter; NH_4Cl 15 g.; H_3BO_3 15 g.; pH was adjusted to 6. Plating was at room temperatures; 0.10 ampere for the above cathode. Plating time for the thinnest deposits was 5 min.

The plated copper foil was then removed from the plate cathode and sheared into ribbons 0.38 mm. (0.015 in.) wide by 2 in. long and two of them soldered by their ends to a platinum wire frame. When the ribbon was fixed to the platinum frame, the copper was dissolved electrochemically. The electromotive force of metals in potassium cyanide solutions indicates that copper in contact with platinum should dissolve readily and that nickel should dissolve with much less ease. The frame with the nickel plated copper ribbons was therefore immersed in a concentrated solution of potassium cyanide. The copper dissolves, going into solution as a complex copper cyanide, while hydrogen gas is evolved at the platinum frame. Heating to about 50° C. accelerates the solution. When action ceases the frame with the thin nickel ribbons attached must be raised very slowly to prevent the surface tension of the liquid from breaking the ribbons.

These filaments appear to possess the electrical properties of bulk nickel. The method described is not restricted to nickel; thin bismuth ribbons have been prepared by the same procedure. (FRANK G. BROCKMAN, research laboratories, North American Philips Co.)

*EDITOR'S NOTE — A bolometer is an instrument for measuring minute quantities of radiant heat by absorbing the heat in a blackened metal strip and measuring the associated change in electrical resistance of the strip. Astronomers have used it to measure the heat of stars. Spectroscopists have used it to explore the infrared spectrum. When associated with proper amplifying and recording devices, a curve-drawing instrument can map the infrared spectral region of hydrocarbon mixtures in 25 min.

Effect of "Fisheyes" on Impact Strength of High-Tensile Manganese-Titanium Steel Plate*

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AS EARLY AS 1863 St. Claire-Deville and Troost observed that hydrogen would diffuse through solid steel, but it has remained for more recent investigators to determine that this smallest and lightest of elements is definitely associated with certain defects found in steel products. In 1907 Sieverts began publishing the results of some theoretical studies of the pressure-temperature-solubility relationships of hydrogen in steel. The use of alloy steels for heavy ordnance during World War I was accompanied by the revelation of faults variously described as "snowflakes", "flakes", "scabs", "lemon spots", "goose eggs", "silver streaks", "shatter cracks", and "fisheyes". Railroads have long been plagued with similar failures in steel rails.

Investigators observed that "flakes" which appeared in tensile fractures and macro-etch tests were associated with nonmetallic inclusions. Logically enough, the earlier theories of the origin of flakes advanced inclusions as their primary cause, and emphasis was placed on metallurgical procedures necessary for the production of clean steel.

With the decrease in heavy ordnance production in the early 1920's American interest in flakes and allied defects waned and, significantly, the technical literature on the topic between 1922 and 1940 is predominantly of German origin. Data accumulated prior to 1935 indicated that flaking in steel was associated with internal stress. However, in 1935 Houdremont and Korschan showed that flaking occurred during cooling from elevated temperatures and was dependent on the rate at which the steel passed through a range of temperature in the vicinity of 400° F. By demonstrating that forging stresses and stresses due to transformation, as well as segregation and gas inclusions, did not in themselves constitute the cause of flaking, these investigators refuted the earlier theories. They also focused attention on hydrogen, the possible effects of which were neglected in earlier theories.

Cramer and Bast reported, in 1939, the results of treating molten steel with hydrogen, and concluded that this gas played an important role in the development of flakes in steel. In 1940 Zapffe and Sims collated the available information and advanced a theory to explain the mechanism of hydrogen embrittlement. Subsequently, Houdremont and Schrader, working from a practical rather than an academic standpoint, reported the results of extensive investigations which proved beyond reasonable doubt that the presence of hydrogen is an indispensable precondition for the formation of flakes.

The foregoing paragraphs have attempted to outline briefly the development of the theories associating certain internal defects in steel products with the presence of hydrogen. A bibliography listing the publications in which these early investigations are described will be found on page 1178. From the available information the following concepts appear to have been established:

1. The solubility and permeability of hydrogen in steel decrease with decreasing temperature.
2. Occluded or trapped hydrogen in solid steel tends to diffuse to the atmosphere and will eventually approach equilibrium solubility conditions.
3. Monatomic hydrogen diffuses more readily through steel than molecular hydrogen.
4. Under certain conditions of cooling, hydrogen gas collects in the vicinity of discontinuities in the metal and attains pressure of sufficient magni-

*The opinions or assertions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

tude to cause local embrittlement or rupture, thus giving rise to "flakes" or "fisheyes".

5. There is a critical pressure and volume of hydrogen required to cause a specific type of defect.

6. Hydrogen may be absorbed from reducing furnace atmospheres and carburizing compounds.

7. Flaking may occur in susceptible steels when they are cooled at a rate exceeding some critical rate between 750 and 100° F.

8. Flaking may be caused solely by the action of hydrogen, but when the hydrogen content is not unusually high it must be assumed that stresses from other sources form a part of the cause system.

9. Superimposed stresses can change the orientation of flaking.

10. Segregation of metallic constituents has little influence on flaking.

11. Certain steelmaking processes are more susceptible to hydrogen absorption than others.

12. Certain chemical compositions are more susceptible to flaking than others.

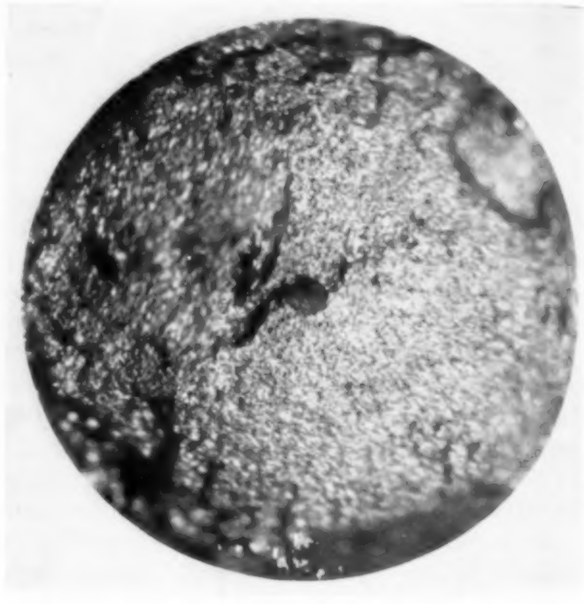
13. Hydrogen is more soluble in gamma iron than in alpha iron.

Kingsley claims to have successfully avoided flakes in over 25,000 tons of alloy steel billets by a cycle cooling treatment. Such a method for the prevention of flakes and allied defects must incorporate the efficient utilization of the foregoing concepts.

The term "flaking" as used herein refers to the phenomenon whereby the wrought metal develops minute, spontaneous, internal ruptures in the absence of externally applied stresses. A distinction is made between "flakes" and "primary crystal boundary cracks" occurring in the ingot stage. Flaking in the above sense occurs only after hot working and is distinguishable from boundary cracks by the smaller size of the ruptures and independence of the primary crystal system. The term "fisheye" refers to a small bright area in the otherwise dull background of a freshly fractured surface. The areas are roughly circular and usually surround a minute void or inclusion, resembling the pupil of the eye. Flakes exist in the material as fabricated and may be observed on machined sections by etching or by magnetic powder methods. Fisheyes do not exist as such in the unfractured metal and therefore do not respond to etching or magnetic powder inspection.

Numerous examples of fisheyes have come to

Fig. 2 — Enlarged View of Fisheye. 8×



the attention of the authors along with other samples of hydrogen-associated defects. They have been observed in the fractured ends of tensile test bars after routine inspection testing of rolled plates and shapes. The majority of them have been found in test bars representing high tensile strength material of Navy welding grade, of the manganese-titanium, manganese-vanadium and manganese-titanium-vanadium types. Examples were found in samples of basic openhearth and basic electric steel. Fisheyes in weld deposits are not uncommon, but their occurrence in hot rolled plates and shapes was considered worthy of attention. Some particularly glaring examples are shown in Fig. 1.

That the fisheyes occur in conjunction with voids or nonmetallic inclusions is clearly shown by Fig. 2 to 5. The transverse ruptures shown in Fig. 5 were observed in the plastically deformed metal adjacent to the fracture and are believed

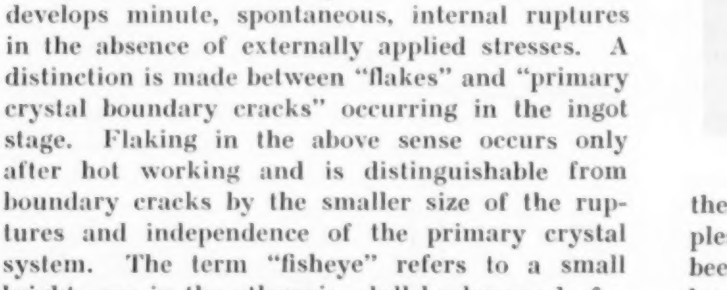


Fig. 1 — Typical Fisheyes in Tensile Fractures of High-Tensile Steel (Manganese-Titanium Welding Grade). 1½×

Fig. 3 and 4 — Longitudinal Sections Through a Fisheye That Discloses a Cavity at Its Base. Left: 4×, unetched; right: 100×, etched

to be incipient fisheyes. Careful microscopic examination of the metal adjacent to the bright areas of a number of fisheyes disclosed no unusual metallographic features which would help to explain them. No other direct evidence that the fisheyes denoted the presence of hydrogen in the steel was sought, since it was considered that this was sufficiently established in the literature (see bibliography, page 1178).

Effect of hydrogen content on the serviceability of the material was investigated by analyzing the results of physical tests. Tensile strength, yield point, and elongation are not reduced below specification limits by the presence of fisheyes. It did appear, however, that ductility was somewhat impaired in that a significant increase in yield point and increase in elongation occurred in comparison test bars which had been allowed to age naturally until such time as the new fractures no longer showed fisheyes. This is shown by Table I, page 1176.

Samples from a total of 85 heats which yielded fisheyes were examined by macro-etching and by magnetic powder methods for evidence of flaking. The results were negative in all heats, which is a strong indication that internal stress conditions in this type of material did not cause spontaneous cracking, at least with the maximum amounts of hydrogen present in the heats which we have studied.

It was further desired to investigate the possible effects of the fisheye tendency on welding properties, fatigue properties, and impact properties, but it is doubtful that either fatigue or welding tests will yield positive results because of the time involved in conducting the tests and the possible alteration of the material under welding conditions. The following investigation of impact properties, however, is believed to be significant.

Effect of Fisheyes on Impact Properties

A 40.8-lb. basic openhearth plate of manganese-titanium steel that showed fisheyes in the original test fractures was selected for testing and was designated as plate 1. The heat from which plate 1 was rolled had the following ladle analysis: C, 0.14%; Mn, 1.30%; P, 0.023%; S, 0.028%; Si, 0.25%; Ti, 0.033%. This plate was sectioned

Fig. 5 — Transverse Ruptures in Plastically Deformed Metal Adjacent to Fracture. 50×, unetched

to provide ten tensile control specimens aligned along both sides of the plate, encompassing the sections designated for various tests, including impact tests. Fractures of control specimens of plate 1 exhibited very few fisheyes and testing was abandoned in favor of plate 2, a 40.8-lb. plate *from the same heat and ingot* as plate 1, but showing the most severe condition of fisheyes so far observed. Three representative control specimen fractures are shown in Fig. 6 at left; see also the physical properties in Table I.

Table I — Effect of Natural Aging on Steel Plate No. 2 Containing Fisheyes (See also Fig. 6)

	REQUIREMENTS	WITH FISHEYES	NO FISHEYES
Age (after rolling)		5 days	32 days
Number of tests		10	8
Yield point, average	45,000 min.	50,870 psi.	48,210 psi.
Standard deviation		750	455
Tensile strength, average	84,000 max.	70,510	70,140
Standard deviation		478	470
Elongation in 8 in., average	20% min.	24.3	27.0
Standard deviation		1.11%	1.47%

The Charpy V-notch impact specimen was used throughout this investigation because of its high sensitivity in detecting the transition of metal from the ductile to the brittle state under high rates of loading. The tests were performed in accordance with A.S.T.M. Tentative Standard E23-41T on Impact Testing of Metallic Materials. They were made on an Olsen impact testing machine of 240 ft-lb. capacity and a striking velocity of 16.7 ft. per sec.

The first longitudinal impact specimens were prepared from the grip ends of the plate 2 control tensile specimens and were notched in a plane parallel to the rolled surface. The specimens were tested at 80 and 32° F. The results were both high and erratic. Even though the results proved to be statistically in control, the dispersion was so great, especially at 32° F., as to preclude further use of the data. (See Table II.)

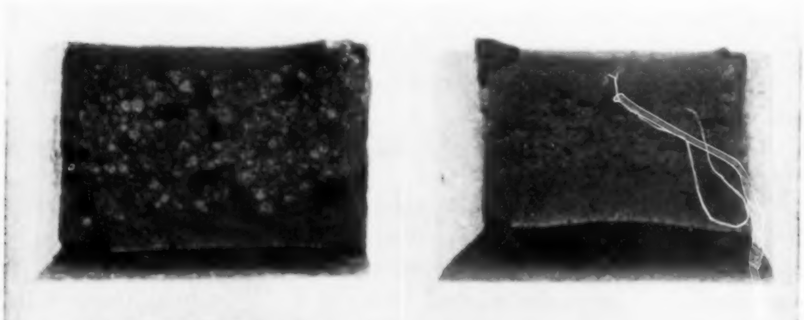


Fig. 6 — Tensile Fractures From Plate 2 (Slightly Enlarged). At left is fracture appearance of specimens broken 5 days after plate was rolled; at right 32 days after rolling

An examination of the impact specimens and fractures disclosed that the erratic results were caused by the presence of laminations, both macro and microscopic, in planes parallel to the notched surface. These laminations prevented the normal propagation of the fracture from the base of the notch.

A second series of longitudinal impact test specimens was then prepared from a section of the same plate. In order to minimize point-to-point variations resulting from the heterogeneity of the plate, alternate specimens were grouped for testing at the specified temperatures. Also, the notches were located normal to the rolled surface in order to subjugate if not entirely eliminate the effects of possible laminations. An attempt was made to remove the uncertain effects of tool marks parallel to the base of the notch by lapping with 240-grit grinding compound while forcing the specimen, together with a small amount of grinding compound, against a revolving section of music wire 0.020 in. in diameter.

Table II — Charpy V-Notch Impact Tests

Temperature of Test	Condition of Test Specimens	Number of Specimens	Average Impact Strength	Standard Deviation	Fracture Appearance*
	Plate 2 (fisheyes); notches parallel to rolled surface				
80° F.	As-rolled	30	177.3 ft-lb.	23.43 ft-lb.	F
32	As-rolled	29	112.1	78.80	Mixed F & B
	Plate 2 (fisheyes); notches normal to rolled surface				
80	As-rolled	31	51.9	10.75	P B
32	As-rolled	31	23.9	8.40	B
80	Artificially aged	23	63.3	16.94	P B
32	Artificially aged	23	30.9	7.32	B
85	Naturally aged	6	82.3	8.30	P B
32	Naturally aged	6	42.7	10.54	B
82	Normalized	6	107.0	4.40	D
32	Normalized	6	107.8	4.42	D
	Plate 3 (no fisheyes); notches normal to rolled surface				
80	As-rolled	27	74.3	2.06	D
32	As-rolled	27	51.7	10.26	P B
80	Artificially aged	25	72.4	2.58	D
32	Artificially aged	27	56.1	7.58	P B

*F indicates fibrous or woody fracture.
D indicates ductile fracture.
B indicates brittle fracture.
P B indicates partially brittle, partially ductile.

It has been suggested during an interchange of letters between George F. Comstock and the present authors (*Metal Progress* for November 1945) that the location of the notch *normal* to the rolled surface is illogical because it does not represent the condition under which plate material would normally be subjected to maximum operating stress. This objection may be adequately refuted by reports of failures of welded hull structures which describe in detail the edgewise propagation of failures through plate materials. Modern welded construction, particularly when welding sequences are improperly or inadequately planned to reduce locked-in stresses to the absolute minimum, undoubtedly imposes edgewise stresses of considerable magnitude on the plate. If, then, it is shown that notch sensitivity is greatest when the notch is normal to the rolled surfaces, it was logical to employ a similar location of the notch in performing the present investigation.

The impact tests on plate 2 were made at two temperatures and under four conditions, namely, 80° F. and 32° F., and as-rolled, artificially aged, naturally aged, and normalized. Since aging at moderately low temperatures is known to accelerate the outward diffusion of hydrogen and thus alleviate the fisheye condition, testing after artificially aging at 400° F. for 8 hr. was considered desirable. Artificial aging could then be compared with natural aging.

In order to determine the relationship between formation of fisheyes and impact properties, the properties of plate 2 were compared with those of plate 3, which was identical in gage and similar in analysis to plate 2 but (so far as could be determined) free from fisheyes. Plate 3 was tested at both 80° F. and 32° F. and in the as-rolled and artificially aged conditions. All of the essential data concerning the impact tests on plates 2 and 3 are tabulated in Table II.

The types of fractures resulting from the impact tests are shown in Fig. 7. They vary in appearance from completely fibrous through various degrees of crystallinity to nearly completely

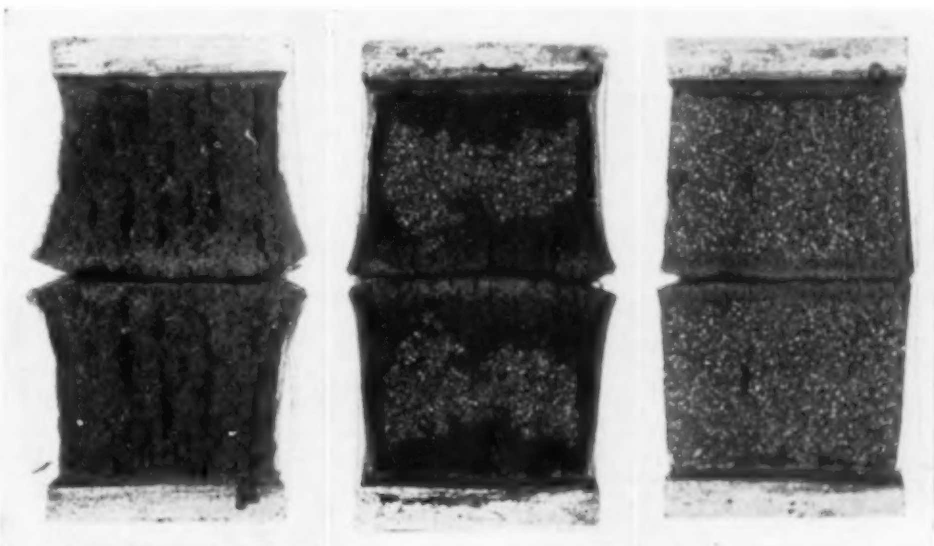


Fig. 7 — Representative Fractures of Impact Test Pieces, 3½×. Ductile at left; part ductile, part brittle in center; brittle at right

crystalline, indicating the progress of transition from the ductile to the brittle condition.

Statistically, the average value and the standard deviations of the impact tests convey the gist of the information. However, since the significance of these statistics is contingent on the assumption that the individual values represent a normal system of chance causes, a criterion of normality is desirable. The data for the impact tests in the as-rolled and aged conditions for each temperature of test are plotted as control charts in Fig. 8 and 9. This convenient criterion leaves little doubt that the data are sufficiently normal for reliable deductions.

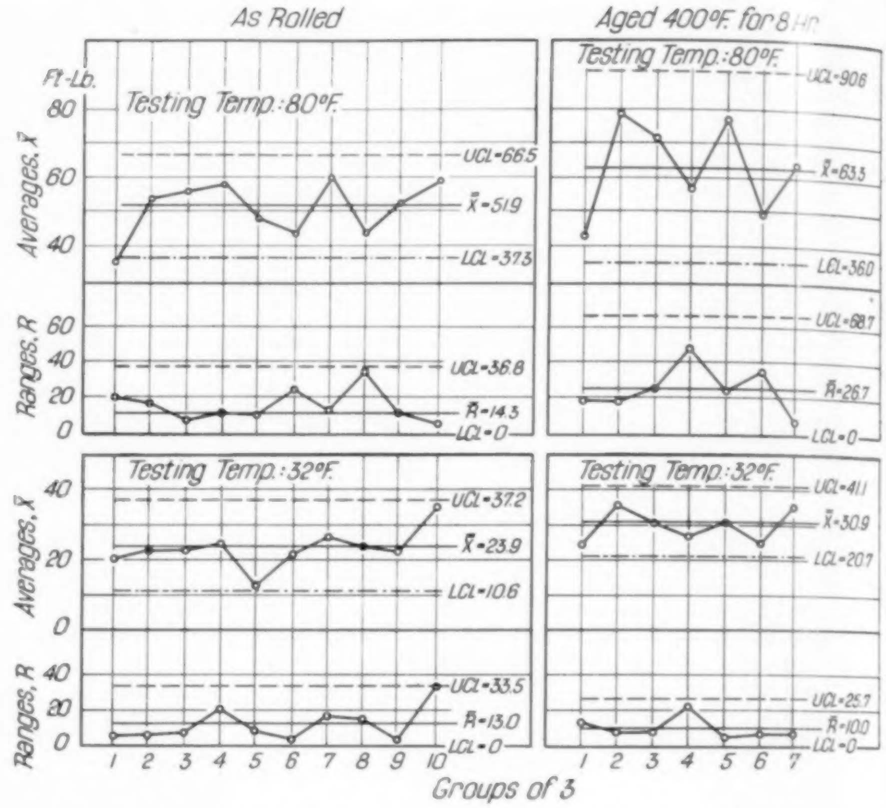


Fig. 8 — Control Charts for Impact Tests on Plate 2 (With Fisheyes)

One important observation made during the course of the investigation deserves mention. Since hydrogen diffuses outward during natural aging, eight unfractured tensile specimens were set aside to age for 32 days at the same time that plate 2 (containing fisheyes) was originally sectioned. Three representative fractures are shown at the right of Fig. 6. The difference in fracture of the two series is obvious; the difference in ductility is noted in Table I. Unfortunately, the rate of diffusion was more rapid than anticipated and consequently no earlier tests were broken to determine the exact condition of the plate at the time the as-rolled impact tests were performed. The important point commercially, however, is that hydrogen, when present in sufficient amounts to cause fisheyes but insufficient to cause flakes under the existing stress conditions, will be dissipated in a short period of time to yield material free of fisheyes. Of course, the voids or inclusions which localized the embrittlement remain as such throughout the life of the material.

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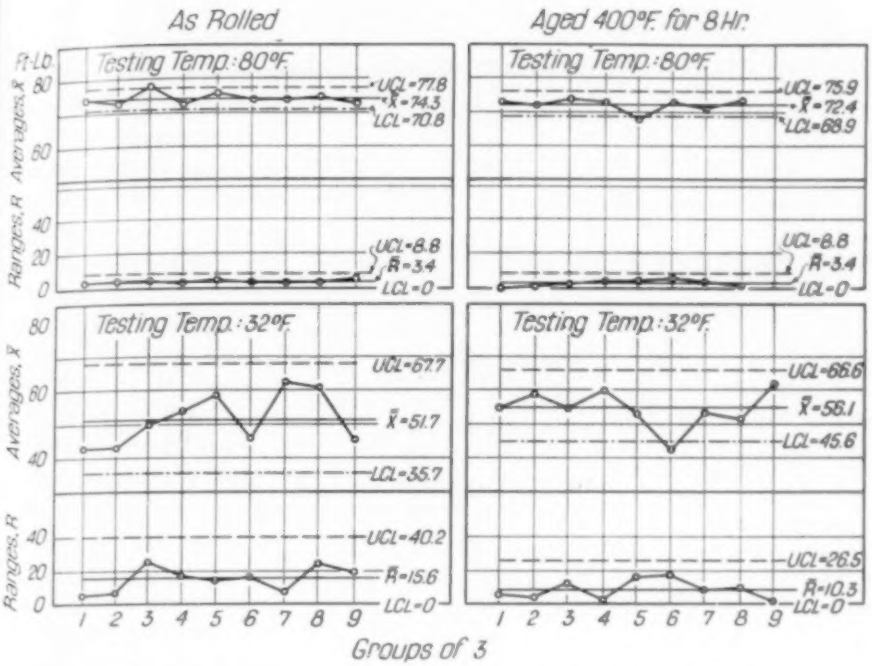


Fig. 9 — Control Charts for Impact Tests on Plate 3 (Without Fisheyes)

Discussion of Impact Test Results

The conclusions which may be drawn from the data presented herein are limited by the small number of test materials and the comparatively narrow range of testing temperatures. The effect of major process variables on the properties of specific samples of material is important and is not covered by this investigation. Table III lists data on impact tests of several heats of Mn-Ti and Mn-Ti-V steel supplied by a manufacturer of high-tensile steels, and the wide variation of values may be attributable to process variables. The presence of occluded hydrogen is one variable that conceivably could exert an influence on all tests.

Although the impact values obtained for the plates investigated by us may not represent exact properties of any other sample of material tested under the same conditions, the effect of the laboratory treatments (particularly those designed to remove the tendency of the material toward fisheyes) should be reproducible on comparable material. The data presented herein have, therefore, been considered with regard to their relative value and variation with the conditions of treatment described.

Various investigators have shown that the energy absorbed in the standard V-notch Charpy impact test of the low-carbon steels varies with the temperature at which the test is performed. A representative curve for energy absorbed versus temperature of test drops sharply as the steel is cooled through the region of room temperature. This sharp drop in energy values characterizes the transition from the ductile condition to the brittle condition. A curve given by Jackson and others (see the bibliography, at left, below) for a steel containing 0.24% carbon and 0.46% manganese is reproduced in Fig. 10. The results of the present investigation are shown on the same plot.

It will be noted from Fig. 10 that baking of the fisheye-free material (plate 3) at 400° F. for 8 hr. had little effect on the location of the test results. However, plate 2 (susceptible to fisheye formation) was improved substantially by baking at 400° F. for 8 hr. and was further improved by natural aging for 100 days. The lines connecting the values at 80° F. and 32° F. do not necessarily represent the loci of values at intermediate temperatures, but are drawn to emphasize

Table III — Charpy V-Notch Impacts on High-Tensile Mn-Ti, Mn-V, and Mn-Ti-V Plate in As-Rolled Condition
(Average of three tests at each temperature)

Heat	Type	Plate Gage	Charpy Values		Tensile Fracture Appearance
			At 78° F.	At −25° F.	
A	Mn-Ti	40.8 lb.	66 ft-lb.	4 ft-lb.	Fisheyes
B	Mn-Ti-V	40.8	83	—	Fisheyes
B	Mn-Ti-V	25.5	83	14	No fisheyes
C	Mn-Ti-V	30.6	11	—	Fisheyes
C	Mn-Ti-V	30.6	—	5	Fisheyes
C	Mn-Ti-V	25.5	17	—	No fisheyes
C	Mn-Ti-V	25.5*	88	—	No fisheyes
C	Mn-Ti-V	30.6	—	3	No fisheyes
C	Mn-Ti-V	30.6*	—	29	No fisheyes
D	Mn-Ti-V	35.7	12	4	Fisheyes
E	Mn-Ti-V	40.8	53	—	Fisheyes
F	Mn-Ti-V	30.6	91	—	Fisheyes
F	Mn-Ti-V	30.6	48	7	No fisheyes
G	Mn-Ti-V	30.6	38	10	No fisheyes
H	Mn-Ti	30.6	61	7	No fisheyes
H	Mn-Ti	30.6	78	8	No fisheyes
H	Mn-Ti	30.6	74	28	No fisheyes
H	Mn-Ti	30.6	72	27	No fisheyes
I	Mn-V	40.8	94	5	No fisheyes

*Normalized at 1600° F.

the relationship between corresponding points. The improvement in impact properties with aging is denoted by the higher average values, the net effect of which is to shift the assumed locus of points to the left. In other words, the temperature range of transition from the ductile to the brittle condition is lowered.

Figure 10 also shows the results of normalizing material susceptible to fisheyes, and indicates that the temperature range of transition is below the minimum temperature used in this test.

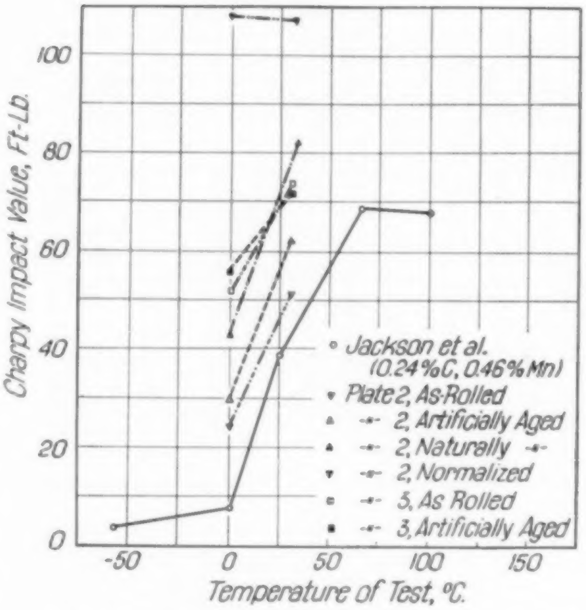


Fig. 10 — Relation of Structure (Fisheyes) and Temperature on Charpy V-Notch Test Results

Examination of the last column in Table II, giving type of fracture, and of the control charts, Fig. 8 and 9, provides supplementary information regarding the relative brittleness of the material under different test conditions. Thus, the crystalline appearance of the fractures and wide control limits of the results of certain groups of specimens may be associated with a steep trend in the curve for energy absorbed versus temperature of test, indicating that the material is in a state of rapid transition under the test conditions. The fibrous appearance of certain other groups is associated with the considerably narrower control limits, suggesting that the material under the applicable conditions of test is in a relatively stable, ductile condition, and that the trend at the point representing that group on the curve should be more nearly level than is indicated by Fig. 10.

It has been assumed that the low impact values observed on the material showing fisheyes were attributable to the presence of dissolved or occluded hydrogen in the steel. Accordingly, the improvement in impact properties of plate 2 after baking at 400° F. and after natural aging for 100 days was to be expected, since both of the above treatments encourage the diffusion of hydrogen out of the metal. Similarly, it may be concluded that plate 3, which did not respond to the 400° F. baking treatment, was relatively free from hydrogen.

Another phase of the problem which has not been further investigated has to do with the presence of nonmetallic inclusions, voids, and other discontinuities known to be present in steel. Hydrogen (one of the factors affecting the occurrence of fisheyes) will concentrate in the vicinity of such discontinuities. In this investigation it is obvious that the distribution of discontinuities in the material is not changed by the treatment of the test specimens. It is, therefore, concluded that the improvement in impact properties resulting from aging was independent of their presence.

A brief survey has been made of the history of hydrogen in steel and the more recent observations on associated phenomena. Presence of fisheyes in tensile fractures of high-strength Mn-Ti steel and their association with nonmetallic inclusions and minute voids have been established. It has been assumed, without any further attempt at proof other than the large amount of published literature, that hydrogen is primarily responsible for fisheyes in this steel. The effect of factors contributing to the formation of fisheyes on physical properties and, in particular, on impact strength of Mn-Ti steel in the as-rolled and aged conditions has been investigated and has resulted in the following conclusions:

1. Artificial aging by baking at 400° F. and natural aging at room temperature for an extended period (approximately one month) improve the ductility of steel subject to fisheyes. This is evidenced by a significant increase in elongation of tensile test specimens and by a decrease of the temperature range in which the transition from ductile to brittle condition occurs in impact tests.

2. Conditions responsible for formation of fisheyes in tensile fractures of high-tensile welding-grade steel plate cause the transition of the material from the ductile to the brittle condition to take place in a temperature range higher than would be expected for similar material not subject to fisheyes. This is evidenced by the standard V-notch Charpy impact tests.

3. Improvement in ductility after aging is associated with the removal of dissolved or occluded hydrogen from the material.

4. Occurrence of fisheyes in tensile fractures of freshly rolled high-tensile steel is not *prima facie* evidence of undesirability of the material from the standpoint of impact resistance, since the disappearance of fisheyes in the course of natural aging is accompanied by improved impact properties.

An Oath for Scientists and Engineers

New York City

To the Readers of Metal Progress:

On looking over the December issue of *Metal Progress* I observe the editorial entitled "An Oath for Scientists and Engineers", and my mind runs back to an *Iron Age* editorial of rather ancient vintage (July 13, 1944), "ancient" when measuring time by the present rapidity of events.

You will note that this editorial was written before the coming of the atomic age, and, as all *Iron Age* pronouncements, it was so complete as to include anything that might happen!

Really, however, I do not feel bad about this, as some Chinaman a thousand years ago probably had the same idea and published it in the leading scientific and technical publication of China, known as The Stone Age.

John H. Van Deventer
President & Editorial Director
The Iron Age

The Iron Age *editorial is reproduced below. It was signed by Mr. Van Deventer.*

The Hippocratic Oath for Engineers

Doctors and surgeons will come out of this war not only with clear consciences but with the heartfelt thanks of humanity regardless of race or party. They have exerted themselves to the utmost to save human life. Engineers, on the other hand, will not be able to have this said of them. They have done a wonderful job in helping to destroy human life. Think of what war would be today without airplanes, rocket guns, tanks, submarines and the countless other instruments produced by engineering genius.

I realize that I am inviting some very caustic comments from my engineering friends in making this statement. They will write me and ask if I would prefer to have them hold back and permit the Axis powers to go forward with their destruction engineering and thus become rulers of the world. And I will have to admit that I would not.

I want to see this war won and when it is, as it will be, a large part of the credit for winning it will go to the engineers and designers of our fraternity. But I want to see it stay won and I think that engineers and designers should have a voice in this too, and not have it left to the politicians after we and the armed forces of the Allies have done the necessary killing and maiming.

Personally, all of the engineers whom I have ever met, of whatever nationality, are peaceable people who like to solve problems rather than to invent problems that will hurt others who may have to solve them. I never knew an engineer who wanted to kill anyone, even though that person might have been a professor who flunked him in physics or mathematics. Most engineers, I am sure, when they invent some new machine have it in mind to make things easier and not harder for people.

This war is the last chance for humanity and for the engineers who are a part of it. For unless, after we win the war, we make it impossible for anyone ever again to practice destruction engineering, none of us will have to die to go to hell.

The robot flying bomb makes that perfectly clear. It has come too late to save the Axis, but give any capable group of engineers ten or fifteen years more to develop and perfect it and there will not be a city anywhere on earth whose inhabitants will not have cause to live in daily and nightly fear of annihilation by explosions, fires or poison gas. If, as demonstrated by the Germans, you can successfully fly a one-ton bomb for sixty miles, it inevitably follows that improvement and development will enable you to fly a fifty-ton bomb not merely a hundred miles but perhaps a thousand. And then where are you?

These implements of destruction could not be made by politicians. They are made possible by engineers and technicians. Even the airplane was first conceived and developed as an instrument for war. That's a heavy responsibility on our shoulders.

Doctors and surgeons take the oath of Hippocrates before they start to practice and live up to it afterwards. They swear that they will use their knowledge and skill to save human life and not destroy it.

If engineers throughout the world would agree to take the same oath, there would be no more war.

The German "Fasteners" Industry

Cleveland, Ohio

To the Readers of Metal Progress:

The undersigned, along with Charles F. Newpher of the National Screw & Mfg. Co., had an opportunity in July of last year to inspect more than a score of plants in the German industry making bolts, screws and nuts. This industry is centered around Düsseldorf, Hagen and Hamburg.

Broadly speaking, the bolt, screw and nut industry in Germany is many years behind either England or the United States. The economic factor behind this is the fact that labor had been plentiful and cheap before the war, so that it was not necessary to devise automatic or mechanical means to produce products rapidly or accurately. As the war took away this native labor, it was replaced by slave labor, and the production was maintained on a fairly constant level, although

quality suffered and much defective material was produced.

Scarcity of alloys early hit the German bolt industry and substitute materials were made mandatory, finally resulting in steels of high manganese as the sole alloy employed. Complaint was always made to us about the quality of the steel. Full of seams, it was not suited to cold heading, and it was difficult to produce an acceptable product. In one factory this presence of seams was so pronounced that the workmen were actually heating connecting-rod bolts — a vitally important product — to a cherry-red in order to roll the threads properly, almost certainly resulting in a decarburized thread of very poor structure.

The high command in Germany failed to appreciate the necessity of fasteners — as was almost the case in the United States — and drafted the skilled labor, technicians and engineering talent freely either for Army service or to supply other manufacturing plants. It was not until 1944 that the scarcity of bolts and nuts had become so serious that it was realized that a mistake had been made and it was then too late to rectify the error. At the end, instances were found where so-called "satchel couriers" would pick up one or two hundred pounds of bolts and deliver them to the assembly lines in an endeavor to get out armament and planes.

Taking it all in all, the German industry presents a sorry picture with no vestige of high production methods in vogue in the United States, and few places comparable with those in England. Methods that passed out of use 30 or more years ago are still in use, particularly on the larger diameter, hot forged bolts. The worst installation witnessed was one producing rivets from cut blanks by means of a belt drop hammer, the belt running over a driven shaft and the drop pulled up by manual tightening of the belt. Cold heading has progressed much further. On the whole, the machines are excellent — more modern than any other equipment. On the other hand, of cut-threading methods the less said the better.

A method of blank rolling to get a smooth finish was also discovered. Coupled with the product of a high speed lathe, this produced a finish better than by centerless grinding. The method was used on "waisted" bolts or studs used in aircraft engines, and consisted of rolling the product between polished and lapped dies. The dies are designed to contact the full width of the reduced or waisted portion and on up into the radii at each end of the reduced portion so that all scratches, tool marks, or fatigue localizers are ironed out beautifully. A very remarkable job is done, highly valuable for stressed bolts. Its success depends on a good finish in the original bolt and an extremely accurate waisted portion as to length, together with accurate setting up of the roll threads.

The ultra high speed lathe mentioned above runs from 1500 to 5000 rpm., depending on work diameter. Full cutting speeds of carbide tools are used. For example a $\frac{5}{8}$ x 12-in. bolt was cut in 68 sec., with 0.1-mm. feed, 0.2-mm. deep, 2400 rpm. The dead center on this lathe is mounted on ball bearings, free to revolve with the work, and is held up to position with air pressure. The tool slide follows a cam, and a steady rest immediately opposite the tool bears against the work (also following a cam) to prevent any spring. There is also a top steady rest.

While leaded steel was used to improve the machinability of nut stock, no hardenability determinations were made, spheroidized stock was unused, age hardening of cold heading wire unrecognized, induction heating unknown, deep freezing of tools and dies was not done, double extruding and controlled bolt tension were unheard of. In fact, most of the plants showed no evidence of any technical improvements since 1937 or 1938.

Roy H. Smith
President, Lamson & Sessions Co.

Ghosts

Beloit, Wis.

To the Readers of Metal Progress:

This jiving skeleton and startled zebra were found in some 75,000-psi. cast iron. Skeptical metallographers may wish to know that the etchant was 10% ammonium persulphate, and the magnification 500×.

Roy O. Johnson
Fairbanks, Morse & Co.

Two Historic Letters About the Copper-Tin Diagram From Roozeboom to Neville

Comments by D. Stockdale
King's College, Cambridge, England

When R. F. Mehl, head of the department of metallurgy and director of the Metals Research Laboratory at Carnegie Institute of Technology, was recently in England, he visited Cambridge and was shown two letters from H. W. Bakhuis Roozeboom to F. H. Neville. He was greatly interested in these letters and suggested that they would be of at least equal interest to other American metallographers.

The letters are dated November, 1901, when Roozeboom was professor of general chemistry and *Rector Magnificus* in the University of Amsterdam, where he had succeeded to van't Hoff's chair in 1896. It will be remembered that Willard Gibbs published his great work on the phase rule in 1876 in the *Transactions* of the Connecticut Academy, a journal difficult to obtain in Europe, and also that Gibbs expressed his results in such mathematical language that their importance was easily missed by the experimental chemists of the day. It was Roozeboom's life work to interpret Gibbs's ideas to the general scientific world and to apply them to the study of equilibrium in heterogeneous systems. His "Die heterogenen Gleichgewichte vom Standpunkte der Phasenlehre" will be familiar to many. At the beginning of this century, then, Roozeboom in Amsterdam was the world authority on the application of the phase rule.*

There were in Cambridge at that time two great pioneering metallographers, C. T. Heycock and F. H. Neville, who worked in partnership. They had established a reasonably accurate practical scale of temperature in 1895 and had spent the succeeding five years in developing the photography of alloys (after having developed and discarded X-ray photography), in establishing the method of quenching alloys, and in the investigation of the aluminum-gold system. By 1900 they had turned their attention to the constitution of the copper-tin alloys, an investigation which culminated in their famous paper "On the Constitution of the Copper-Tin Series of Alloys", read before the Royal Society as the Bakerian Lecture in 1903, and published in *Philosophical Transactions* of the Royal Society.

That as early as 1901 Heycock and Neville knew much about the bronzes can be judged from four publications:

1. Report to the British Association for the Advancement of Science on the Chemical Compounds Contained in Alloys (1900).
2. Report to the British Association for the Advancement of Science of the committee appointed to investigate the nature of alloys (1901).
3. "On the Results of Chilling Copper-Tin Alloys", *Proceedings* of the Royal Society, V. 68, 1901, p. 171.
4. "On the Constitution of Copper-Tin Alloys", *Proceedings* of the Royal Society, V. 69, 1901, p. 320.

The correspondence with Roozeboom was initiated by Neville. His first letter is not extant, but there is reason to suppose that he sent copies of several papers to Roozeboom, requesting him to consider them from the point of view of the phase rule. Roozeboom certainly received the second report because his reply consisted almost entirely of a discussion of the diagram included in it. We reproduce neither the diagram nor the reply because the fuller diagram reproduced from the Bakerian Lecture of 1903 is more illustrative of the discussion (Fig. 1, page 1184), and because the points raised in it are presented with greater clarity in the second letter.

An exception, however, is contained in a paragraph dealing with the equilibrium between the α and β phases. The peritectic reaction and the growth of the α at the expense of the β evidently aroused great interest on the part of Roozeboom,

*For an appreciation of Willard Gibbs and his work see *Metal Progress* for May 1939, p. 477.

for he wrote, "One of the most remarkable features is that you have in two instances demonstrated the direction of 1C′ as proceeding to the right. First in the systems between B and L wherein the α crystals *grow* below b1C. Then in the system between L and C, viz. 14%. Here you have above 1C some (few) α crystals (according to your photography). Somewhere below 1c you have none, because all is transferred in β crystals. Below 600° you pass the curve 1C′ and α reappears in the photograph. It is entirely impossible to understand such a fact without the interpretation the figure gives."

We reproduce the first few lines of the second letter, its second page, which is of particular interest in that it contains two of Roozeboom's original sketches, and his closing words. The letter is transcribed completely below, followed by comments on points of interest. Another of Roozeboom's sketches is reproduced in the transcript, to illustrate his third remark. The lettering of this sketch is not in exact conformity with that of Fig. 1, but the meaning appears to be clear.

In the transcriptions we correct neither the errors in grammar nor those of spelling. Both are peculiarly attractive and neither detracts in the slightest from the dignity of a great man.

Roozeboom's Letter

Dear Mr. Neville,

Your letter has not been too long. On the contrary — my interest in your results is so great, that I can't refer from writing you once more. Firstly to present my renewed thanks for your communications and photographs.

Then I would suggest the following remarks.

1. The Difference between the point C′ and X. In the eutectic point the β mixed crystals should split up into α and Cu_4Sn. Might it not be possible that in all the mixtures (to the left of C′) which contain already α the Cu_4Sn come always at the right temperature of the eutectic point, but that reversedly in the mixtures to the right of C′ which contain before already Cu_4Sn the α comes always a little too late (by a retardation of building) so that you find *practically* the building of the eutectic mixture on this side at a somewhat lower temperature?

In the broader paper of Mr. Steyer which is in preparation, we have also some such irregularities. And — to confess the truth — I had at the time of the exposition of my theory of the transformation of the mixed crystals much doubt about this

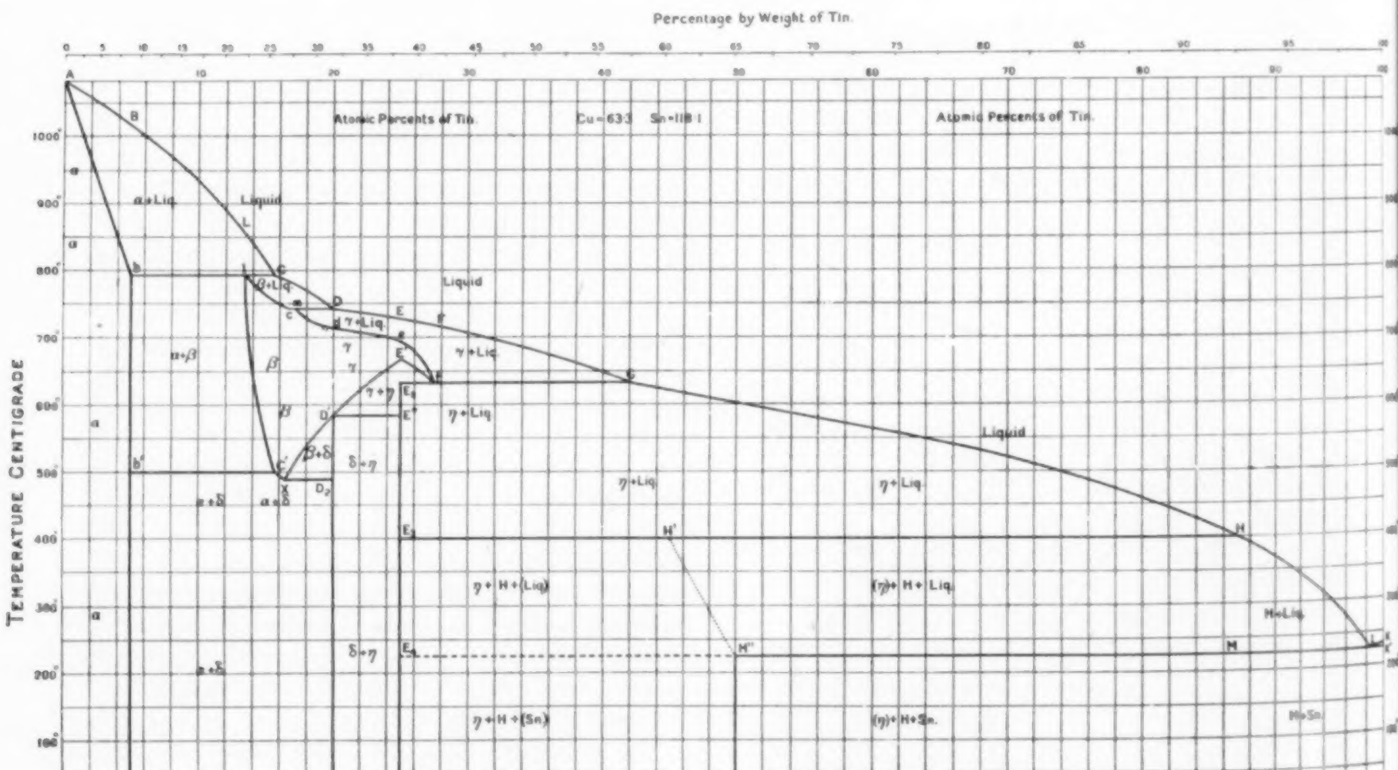


Fig. 1 — Equilibrium of the Copper-Tin Alloys. Reproduced from the Bakerian Lecture of Heycock and Neville; Philosophical Transactions *of the Royal Society (London), V. 202A, 1903, p. 1*

PROF. DR. H. W. BAKHUIS ROOZEBOOM.

Amsterdam, 21 Nov

Dear Mr Neville.

Your letter has not been too long. On the contrary — my interest in your results is so great, that I can't refrain from writing you once more. Firstly to present my renewed thanks for your communications and photographs.

point — whether all these fair things would ever be demonstrable, and it has wondered me very much that in so many cases these *solid* solutions show no greater retardation than those, we have as yet observed.

2. As to the greater concentration than 25%, I have entirely forgotten, in writing my first letter, that we had already some knowledge upon the freezing line till 100% Sn. The information your letter contains and the beautiful and expressive poto's give however, I think, very much more definite results than ever before and I hope that you will have the success of *wholly* elucidating this exceptional interesting system.

Especially I wish to congratulate you on the detection of the process at the temperature E_2fG, where mixed crystals $f \rightarrow Cu_3Sn +$ liquid G by cooling.* Have you could observe the formation of some liquid when passing this temperature? Or have you deducted this phenomenon from the direction and intersection of the curves? Because it is an entirely *new* phenomenon, it were interesting if one could show it.

If we accept for E_2: 25 for f27 and for G50 the transformation would become

$$25\ Cu_{73}S_{27} \rightarrow 23\ Cu_{75}Sn_{25} + 2Cu_{50}Sn_{50}$$

and so when we had the initial composition of the utmost quantity of liquid which could be obtained would be $\pm 1/10$ in weight of the total mass. Can this quantity be seen between the resulting solid crystals?

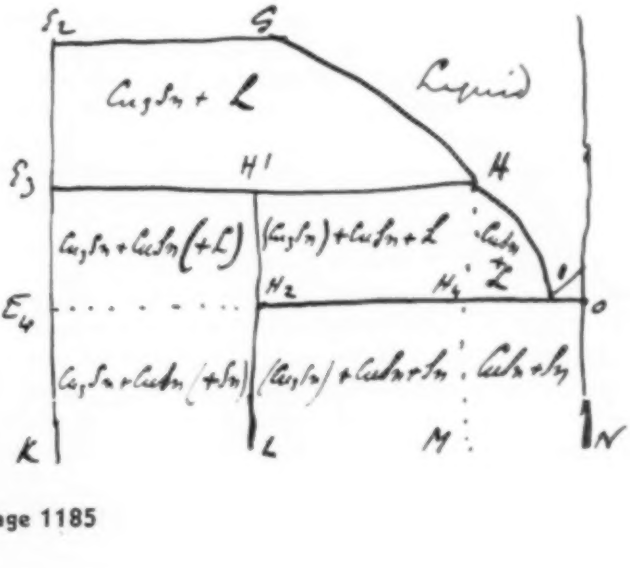
The case in which you obtain such a transformation is one I had *not* foreseen. I myself had foreseen another case, when the transformation curves* DB and DA of a substance which was mixed with another did intersect the freezing curves of the α mixed crystals EC EB. Here we would also have the transformation

mixed cr.B $\rightarrow$ mix. cryst A + liquid C.

My pupil Dr. van Eyk has sought for an example but not found a good one. I have indicated such a figure in Zeit.f.phys.ch., 30, 427.

So you will conceive with how much pleasure I have noticed your observation.

3. As to the transformation below e_3H_1H I would suggest to represent E_4H_2 and HH_4M by dotted lines. H_1H_2L and H_2H_4O indicate the bordering lines separating the different systems which would represent the stable equilibria. The dotted lines may then represent the previous complexes of *three* phases which practically may be



*See the sketches in the letter, page 1186.

Especially I wish to congratulate you on the detection of the process at the temperature $E_2 f G$, when

mixed crystal $f \rightarrow Cu_3Sn$ + liquid G. by cooling. Have you could observe the formation of some liquid when passing this temperature? Or have you deducted this phenomenon from the direction and intersection of the curves? Because it is an entirely new phenomenon, it were interesting if we could show it.

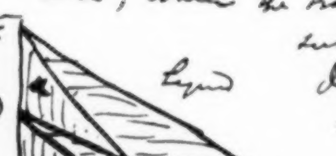
If we accept for E_2: 25 for f 27 and for G. 50 the transformation would become:

$$25\ Cu_{73}S_{27} \rightarrow 23\ Cu_{75}Sn_{25} + 2\ Cu_{50}Sn_{50}$$

and so when we had the initial composition f the utmost quantity of liquid which could be obtained would be ± 1/10 in weight of the total mass.

Can this quantity be seen between the resulting solid crystals?

The case in which you obtain ~~this~~ such a transformation is one I had not foreseen. I myself had foreseen another case, when the transformation curves DB and DA of a



substance which in mixed with another did intersect the freezing curves of the α mixed crystal EC EB.

Then we would also have the transformation mixed cr. B → mix cryst A + liquid C.

observed and by inscribing the third phase which normally should not exist between brackets, as indicated in this figure, I venture that the right understanding might be obtained.

As to the modification of Sn which comes below 20°, if your interpretation is right, it would only present itself in the conglomerates CuSn + Sn and ever at the same temperature. The only interesting point would be whether the Sn in this conglomerate does present the transformation. When you have not time, this point could perhaps be studied here, the more so as we know all the tricks of this transformation.

5. Lastly I have a demand.

Dr. van Eyk, now teacher at the Military Academy, has the purpose to take part together with Dr. Reinders, whom you have seen two years ago, in the research on metalls. He would appreciate very much if he could see some of your installations and would have the opportunity between 21 December and 2 Januar or from 6-13 Januar. Have you any opportunity to show him some things and to talk a little with him one of these days? Be so kind as to write that to me. I am asking the same to Prof. Roberts Austen.

Yours sincerely,

H. W. Bakhuis Roozeboom.

Notes and Comments

1. Roozeboom in his first letter and again here insists that the phase disposition as shown along $b'C'XD_2$ (Fig. 1) cannot be correct because it is in violation of the phase rule. The β phase must be of constant composition when present in stable alloys containing α and γ. Heycock and Neville never fully realized the extreme slowness with which certain changes in the solid phase take place. We know now that the eutectoid transformation takes place at a constant temperature

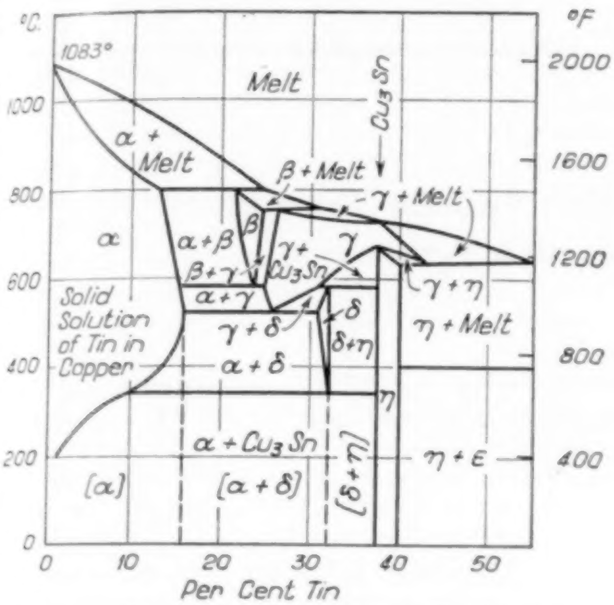


Fig. 2 — Copper End of the Copper-Tin Diagram (A.S.M. Metals Handbook, 1939 Edition, p. 1365)

near 520° C.; they had "retardation of building" on both sides of X.

The paper by Mr. Steyer cannot be traced.

2. The partial melting of the 27 atomic per cent tin alloy on cooling through 635° C. is shown clearly by Fig. 69 to 71 of Heycock and Neville's Bakerian Lecture. We do not know if this evidence was in existence when Roozeboom wrote.

There does not now seem to be a substantial difference between Roozeboom's two sketches. The view that Heycock and Neville took of the γ and η area (Fig. 1) is somewhat doubtful. Presumably they thought that the whole area, $E'D'E''E_2fE'$ was filled with $\gamma+\eta$. It would then have been more in conformity with modern ideas if they had joined E_2E' to denote a narrow field in which η must exist as a single phase. Once it is recognized the η does exist as a single phase over a definite if narrow range of composition, the whole matter becomes much clearer. The general resemblance between Roozeboom's second figure and the accepted diagram as given in Metals Handbook, 1939 Edition, p. 1365, is remarkable.

Dr. van Eyk is the Cornelis van Eyk who worked with Prof. Ernst Cohen on the allotropy of tin and who also carried out important work on systems containing thallium nitrate and another nitrate.

3. This suggestion of enclosing a metastable phase in brackets was adopted, with acknowledgment to Roozeboom, in the paper on the "Constitution of Copper-Tin Alloys" read by Heycock and Neville before the Royal Society on Dec. 12, 1901. Publication in that year seems to have been a much speedier process than it is today!

4. No record of an investigation either by Roozeboom or by Heycock and Neville of the effect of copper on the allotropic transformation of tin has been found.

5. W. Reinders carried out an early investigation on the constitution of the alloys of antimony and tin. His name is probably better known in connection with his work on the equilibrium between silver amalgams and aqueous solutions containing silver and mercurous nitrate *(Zeitschrift für physikalische Chemie*, V. 54, p. 609).

Sir William Chandler Roberts-Austen was professor of metallurgy at the Royal School of Mines, London, from 1880 until his death in 1902, and at one time was deputy master of the Mint. He will be remembered primarily for his work on the diffusion of metals, but he carried out many other researches which are recorded in the first five reports of the Alloys Research Committee of the Institution of Mechanical Engineers and elsewhere, and which included investigations of the constitution of steel and bronze. A sympathetic article on his life and work was written by his former associate, the late Alfred Stansfield, and published in *Metal Progress* on the 100th anniversary of his birth (December 1943, p. 1113).

Have you any opportunity to show him some things and to talk a little with him one of these days? Be so kind as to write that to me. I am asking the same to Prof. Robert Austen ..

Yours sincerely
H W Bakhuis Roozeboom

Steel Melting

A.I.M.E.'s Openhearth and Blast Furnace Committees Discuss Postwar Production Problems

Reported by Ralph W. Farley
Asst. Mill Metallurgist, Chicago District, Republic Steel Corp.

THE 29TH ANNUAL conference of the National Openhearth Steel Committee and the Blast Furnace and Raw Materials Committee of the American Institute of Mining and Metallurgical Engineers was held in Chicago April 24, 25, and 26, with a total registration of 965.

The openhearth committee started its meeting on Wednesday with a plant visitation to the Defense Plant Corp. works of Republic Steel Corp. in South Chicago. Points of interest included the electric and tilting openhearth furnaces, mold preparation building, rolling mills, soaking pits, and chemical and metallurgical laboratories. This plant was briefly described by the Editor of *Metal Progress* in his "Critical Points" for January 1944. Of especial interest to visitors was the control of the soaking pits, in which gas and air flow are controlled by radiation pyrometer equipment and recorded in such a manner as to show when ingots are thoroughly soaked. The rolling mills are lined up for production of a wide range of bloom and billet sizes without reheating by progressive reduction through one, two, or all three mills but are equipped with optional facilities for transfer and cooling of any intermediate size, and furnaces for reheating or wash heating. Crop ends are delivered to cars by a conveyer and separated by analysis. Samples cut at the shears are diverted to a second conveyer and delivered to a test room for identification and preparation. Communication between all work stations is maintained by both voice and Telautograph systems.

The tilting furnaces are of 200 tons capacity, and the electrics 70 tons. The shop is arranged for transfer of hot metal from one of the openhearths to a waiting electric furnace for triple refining, or for finishing heats started in the openhearth from hot metal charge, or for complete refining in the electrics from cold charge.

Visitors were impressed with the size and facilities of the laboratories. Considerable interest was shown in the spectrographic installation in the chemical laboratory, where much of the preliminary and ladle analysis is now done by this method.

The conferences got under way on Thursday, with General Chairman A. P. Miller of the openhearth and A. J. Boynton of the blast furnace committee presiding at simultaneous sessions.

Openhearth Problems

In the openhearth meeting Mr. Miller announced the McKune Award to Taylor and Woods of American Rolling Mill Co. for a paper on "A Statistical Study of Factors Affecting Openhearth Production Rates". This study explains not only which factors are affecting production rates, but also gives a quantitative evaluation of the effect of each factor, within the experience of the very large amount of data collected by them.

In a session devoted to operations of the basic openhearth, the loss of production caused by delay in charging was pointed out, and some improvements made to speed up charging operations were described. In one shop, heats with high hot-metal charge are 45 min. faster than low hot-metal.

Conflicting experiences were cited by two speakers in a comparison of furnaces having one checker and those having two checkers at each end. It was suggested that certain fuels may require larger chamber volumes — thus in one instance favoring removal of the division wall to form one chamber.

The perennial discussion about the relative advantages of limestone and lime for openhearth use was resumed, this time dwelling on sulphur and silica contents and physical sizing of the flux.

Stone contains 0.25 to 0.4% total sulphur, but largely as sulphate. Sulphur content of lime is somewhat higher, because of concentration in calcination and absorption from fuel, but it usually contains less than 0.7% S and 1.75% SiO_2. Tests conducted in one shop over a period of six months have shown 2 to 4-in. stone to be as good in many respects as 8 to 12-in. The smaller size is believed to clear up slowly, but comparisons of furnace time and stone used were favorable. Cooperative study of desirability and availability of stones was proposed.

In a paper by J. S. Griffith and M. Tenenbaum of Inland Steel Co. on the rate of slagging or solution of stone, the formation and dissolution of the calcium silicate rim about the lime particles were described. Petrographic slides demonstrated that the coarser-grained stones form weaker rims, allowing faster penetration of the slag and speeding up the rate of solution.

In the discussion of pig iron preparation, it was explained that soda ash treatment for desulphurization is satisfactory from the openhearth standpoint if carried out properly and if the slag is skimmed. Sulphur can be brought to a suitable level. Various methods were described; the speaker favored starting the reaction in the runner by a regulated feed of soda ash. One operator reported the adaptation of a cupola to melt scrap iron and supply pig for the openhearth charge.* Soda ash is fed in for desulphurization.

In using coke and graphite as substitutes for carburization by pig iron, control can be as accurate as with customary charges, provided that blowing and floating off are avoided. About twice as much carbon seems to be required in the form of coke as when it is introduced in the pig. One operator finds the heat time is increased as much as 1 hr. for one-half replacement by coke; maintenance costs are also increased.

A report on electrolytic manganese elicited discussion by various operators, but none reported unusual results for the applications tried. This material has a purity of 99+% and is practically carbonless. Its obvious importance for certain special applications cannot be overestimated.

Replies to a questionnaire on preliminary tests for carbon, manganese, sulphur, phosphorus and the common alloying elements disclosed the time-saving advantage of the magnetic method for carbon and the spectrographic method for metallic and metalloid elements. By spectrograph the minimum total time reported (test to results) was 12 min. for Mn, Si, Ni, Cr, Mo, Cu, and Sn. Time required for carbon by volumetric method, phosphorus by titration, sulphur by combustion, and FeO of slag compares favorably with the fast time for alloys on the spectrograph.

*See the description of such a plant at Sheffield Steel Corp.'s plant in Kansas City, in "Critical Points" for January 1943.

Acid Openhearth Operation

Under the acid openhearth research program, a study of the measurement of slag fluidity has culminated in specifications for a standard test. The relationship of changes in slag fluidity to physicochemical processes in the slag and bath was pointed out. The standardization of this test, and new knowledge of its relation to changes in the bath, should greatly enhance its usefulness in acid openhearth control.

Attention was given to special deoxidizers for acid steels. One operator pulled transverse tests and observed increased ductility from large ingots treated with the grain refiner and deoxidizer known as Ferro-Carbo. Another reported a definite grain coarsening with this same material.

In the session on metallurgy, attention centered on the application of physicochemical data to the openhearth process, including a discussion of factors affecting excess air requirements to burn all carbon and hydrogen in the melting chamber. A good method of control would be by excess oxygen in the waste gases, but present equipment is not adaptable to this method.

In a discussion of steam versus preheated air for atomization of fuel oil, it developed that production rates favor air but the initial cost is greater. Apparently, further study will reveal whether any net saving is to be realized.

Slag-Metal Reactions

Two papers on slag-metal relationships presented by John Chipman and coworkers before the annual meeting of the A.I.M.E. last February were abstracted and discussed. Sulphur equilibria between liquid iron and slags are controlled almost entirely by the excess base in the slag. These studies indicate that sulphur distribution is essentially independent of such factors as iron oxide content, added fluorspar, MnO (except through its basic nature), and temperature within the range of 2800 to 3000° F. The results lead to the rejection of such reactions as $FeS + CaO = FeO + CaS$ as the desulphurization mechanism, and represent it as a matter of solubility of sulphides in slag, increasing just about linearly with increase in slag basicity. Basicity is expressed as excess base or acid in mols per 100 g. of slag. The combining proportions for neutrality are given by the authors as CaO, MnO, and MgO equal in basic reaction on

a mol-for-mol basis, and 2 mols base to neutralize 1 mol SiO_2 or Al_2O_3, 4 mols base for 1 mol P_2O_5, and 1 mol base for 1 mol Fe_2O_3.

In discussion on the practical aspects of sulphur elimination, the major sources of sulphur were considered, such as scrap, hot metal, fluxes, roll scale, and fuels. Flushing off slag is advantageous. The equilibrium value for sulphur ratio between slag and metal in refining a low-carbon heat reaches a maximum at about 0.8.

Dephosphorization may be represented by the reaction $2P+5O+4CaO=4CaO \cdot P_2O_5$, with equilibrium in this reaction showing a strong dependence upon temperature. The conditions favoring dephosphorization are *(a)* lower temperature, *(b)* higher iron oxide content of slag and metal, *(c)* high base-acid ratio, *(d)* higher MnO and lower SiO_2 in the slag. Both the elimination of phosphorus from the bath and the prevention of reversion must be kept in mind. The conditions for dephosphorization given above are equally essential to hold phosphorus in the slag on blocking the heat. Benefits are gained by control of the analysis of the charge and hot metal — low phosphorus and silicon, and high manganese. Silicon should be kept as low as possible at the blast furnace; if the silicon content of hot metal is high, the flushing of slag in the openhearth has a distinct advantage.

Ladle reactions in rimmed steel have been studied to find their dependence upon operating variables. Occurrence of reactions is measured by existence of wide variation in ladle manganese. Such reactions are found to be favored by a higher state of oxidation of the bath, and are often associated with ladle skulls.

T. E. Brower and B. M. Larsen's paper on oxygen in liquid openhearth steel was also abstracted and discussed. Use is made of the excess of oxygen over that corresponding to equilibrium with CO at one atmosphere, taking $[C]\times[O]=0.00222$. Excess oxygen is found to return to the range 0.015 to 0.025% when the bath is in a steady state — that is, when it is in a normal boil and close to equilibrium conditions except for carbon and oxygen. The oxygen dissolved in steel in this steady state is found to depend essentially upon the carbon content. No correlation can be found between excess oxygen and such factors as rate of carbon drop, slag basicity and fluidity, or temperature. Excess oxygen correlates with the activity of oxygen in the slag, but not with the FeO content. Wide variations in rate of carbon drop occur at equal values of excess oxygen; the authors' studies lead to the conclusion that this depends more upon the ease of bubble formation. Faster carbon drops occur on new and unglazed bottoms, which favor bubble formation.

Quality of Steel

J. W. Halley's paper on grain growth inhibitors presented before the February meeting was reviewed. Coarsening temperatures were found by maintaining a constant gradient over the length of a bar in a special furnace, and temperature curves were exhibited for various elements. Results vary with varying carbon contents. In discussion it was pointed out that coarsening must depend upon resolution of the inclusion to which is attributed the blocking of grain-growth, and some revisions in this concept were suggested, as for example AlN for Al_2O_3. The role of silicon as an assisting element was suggested to explain discontinuities in curves for zirconium and vanadium.

In openhearth practice to meet hardenability requirements, it is essential to restrict the aim for each element to that portion of the specified range which will yield the required result. Such aims must be balanced in a manner to avoid setting a restriction in any one element that will be unattainable in practice. Adjustments are made for residuals after melting in. Test methods and calculation of hardenability were described. One operator reported that multiplying factors are expressed as logarithms and posted in the shop to enable melters to "melt hardenability". Good agreement has been found between forged and cast tests. Important factors emphasized in presentations on the subject of "Surface Quality of Carburized Steel" included selection of raw materials, melt carbon, bath activity, use of spiegel reboil, deoxidation, sulphur content, soaking pit practice, mold design (small corner radii favored).

Special killed steels for deep drawing are deoxidized with aluminum, some operators adding shot aluminum to the tap stream. Some shops cut down scabs by placing a cylinder of 18-gage sheet steel in the mold; primary splash is kept off the mold wall by pouring in the center of the cylinder.

Use of sodium fluoride and mechanical jarring improve surface quality of rimmed steel with 0.20% carbon. Other factors are tap carbon, rate of rise in molds and height of pour.

Furnace Construction and Maintenance

Some substantial savings in time and maintenance expense were revealed by the use of labor-saving devices. B. D. McCarthy of Republic Steel Corp. illustrated by moving pictures how a car in the slag pocket removes as much as 55 cu. yd. of slag and sand wall in one pull. This eliminates blasting and damage to the furnace. Use of the car, said one operator, allows bricklayers to start

24 to 36 hr. sooner. The car pulls best when it is as hot as possible. Conveyer and handling systems for bricks also provide substantial labor savings. In one shop steel supports for roof centers are cutting downtime of rebuild and man-hours very substantially.

Good experience was reported with several installations of the vacuum type of flue-cleaning equipment. The dust collectors dump automatically, so a costly and hazardous operation is eliminated. One plant uses a turbine-driven cleaner employing revolving chains as buffers, in conjunction with the vacuum system.

The discussion on fully rammed versus partly rammed versus dead-burned magnesite bottoms brought out a diversity of experience. With fully rammed bottoms an idle furnace can be put in production more quickly, but while some operators found less average bottom delay per heat, others reported less delay for the sintered bottoms. For the most part, dead-burned bottoms (or partly rammed bottoms surfaced with sintered magnesite) will be used except in emergency. Delay per heat does not adequately describe the condition of bottoms. Sample drilling is used to supplement this knowledge; experiments indicate that the condition of a bottom over a long campaign may be dependent more upon operations and maintenance than upon the original installation. One speaker recommended that judgment on fully rammed bottoms be withheld until effects of a long shutdown are better known.

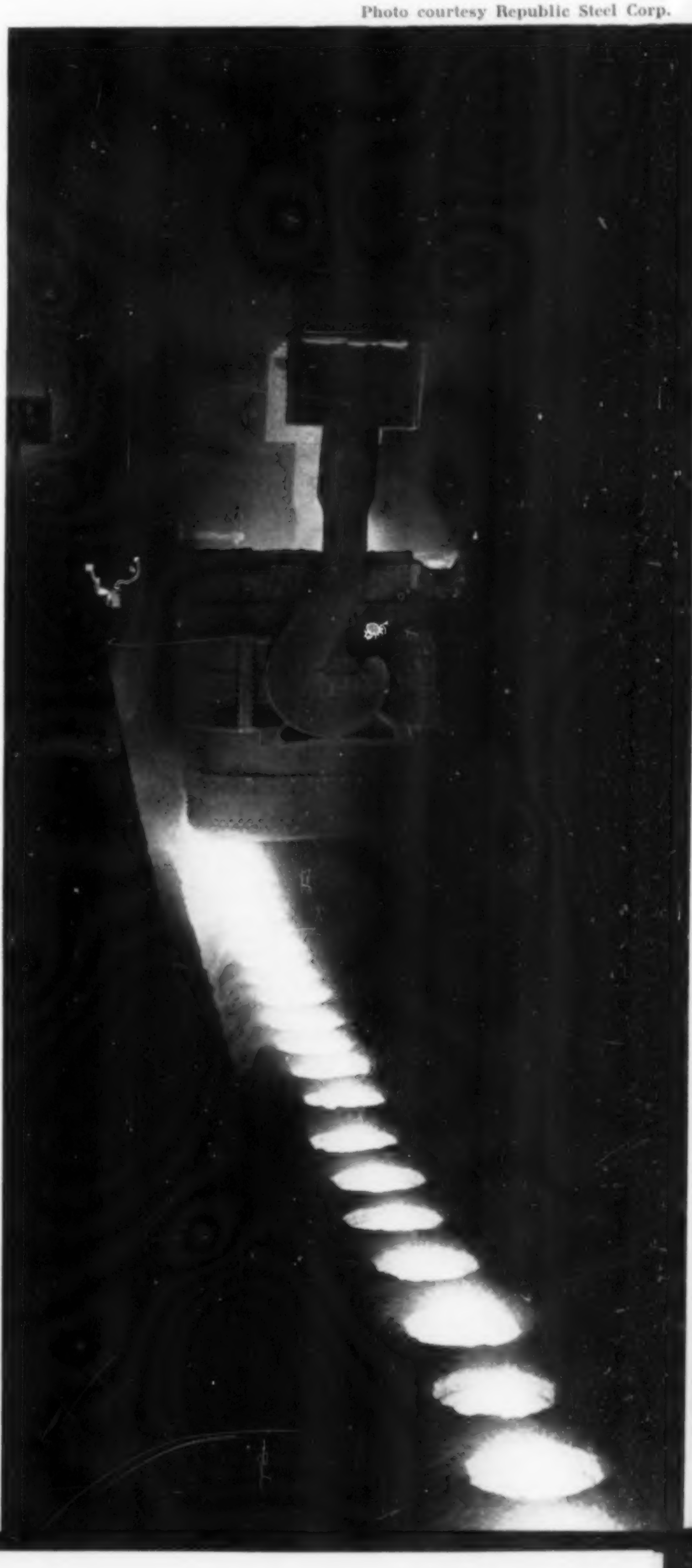
Spraying with pitch, tar or an asphalt paint has been successful in maintaining bottoms through a long shutdown.

Reports on refractories and masonry resulted in some interesting contributions. One operator found a decrease in repair time with an all basic brick furnace; furthermore, he uses only 2 lb. of basic brick per ton of steel produced as compared to 15 lb. of silica brick per ton of steel. Production was increased 12½% with an expected saving of 7¢ per ton of steel. Another operator reported good results from the use of basic end walls and a silica roof.

Discussions of basic rammed doors were supplemented by slides illustrating several types. All operators reported increased door life when using a basic lining; the average life of this type of door is reputed to be 18 times that of silica-lined doors.

A paper on a method of evaluating the quality of firebrick included a discussion of interpretation of certain test results. In the use of superduty firebrick for mixer linings as compared to regular brick, the average tonnage of steel produced per lining increased from 26,970 to 44,063, while cost was cut from \$0.065 to \$0.032 per ton. Insulation of the openhearth increases production and decreases costs by eliminating air infiltration, thus also permitting the determination of fixed air requirement. Fuel costs are directly decreased by conservation of radiant heat. An actual increase in refractory life because of more uniform temperature within the refractories was cited by some operators; all reported fuel economy and increased

Photo courtesy Republic Steel Corp.



production from the use of openhearth insulation.

Maintenance of slag thimbles and cars appears to be chiefly a question of care in their use and regular inspection. Some rules to improve thimble and car life are: Pour in center; avoid boilovers; lubricate frequently and thoroughly; repack journals carefully; use dust guards; keep couplings and safety devices in good shape; use expansion bands to avoid buckling. Stickers may be caused by hot steel, pouring off center, or overloading and slow tipping. Spraying with a bone ash preparation helps to prevent stickers. Some use a plugged hole in the bottom rather than a drill to push out stickers. Before pushing, the slag should be cooled and cracked.

A new Michigan magnesite is a synthetic product derived from $MgCl_2$ from brine. Kiln-sintered to 3200° F., the material sets hard and cracks little on cooling. High temperature, extra time, and addition of SiO_2 are required to burn in a bottom of this material.

Miscellaneous Operating Details

A recording bath pyrometer of the radiation type was described. The device seems quite practical and serves notice that temperature prior to tap will receive more and more attention. The consensus of papers on the effect of temperature on macrotests, cleanliness and grain size was that intermediate temperatures give the best results; excessively hot or cold heats are, in general, somewhat dirtier.

Reports on the use of thin-walled molds were somewhat confusing, some operators claiming longer mold life and others shorter. No one seemed prepared to report conclusive experience on the quality of steel produced from thin-walled molds. Use of plain, rippled, fluted, and corrugated molds was debated. One operator reported definitely better surface from fluted molds, but after 30 to 40 heats the surface quality became worse than that from molds with plain walls. Another manufacturer reported good results from molds having a corrugated bottom portion and a plain-walled top portion. Frequency of use affects the length of mold life. Solid-bottom molds have the advantages of less "fishtail", no bottom-sealing difficulties, and fewer mold stickers.

Powdered pitch for mold coatings is favored by many over tar because of less fumes, but the irritation caused by pitch is still a problem.

Reports on carburized and tarred nozzles showed that carburized nozzles produce a smoother stream but erosion is about the same as with ordinary clay nozzles. Tarred nozzles are stronger and tougher than ordinary nozzles and will withstand the pressure of the stopper rod better, resulting in less cracking of the nozzle.

Ore Supplies

The Blast Furnace and Raw Materials Committee held sessions on coal, refractories, and ore. The coal session was devoted to new developments in coal washing practice and the selection of suitable low-volatile coking coal for metallurgical coke. Refractories discussed included blast furnace hearth and a survey on the tapping hole. Intelligent reporting of these subjects is somewhat over the head of a steel mill metallurgist.

An excellent and forthright discussion of ore reserves and characteristics of future ore supply, however, was of compelling interest to the metallurgical engineer as, in fact, to everyone. A critical analysis of ore reserves was an alarming report on the exhaustion of material available to open-pit mining methods. Production of mines to date, however, has frequently exceeded the reserves estimated earlier. Furthermore, exhaustion of the open pits will be characterized by a gradual decline in their rate of production over many years, supplemented by an increased production from underground deposits and of lower grade ores of about 30% iron, as fast as the mining and beneficiation methods necessary for economical production can be developed. Such low grade deposits are known in the old ranges, and their geology is well known. It may be possible to concentrate them without fine grinding.

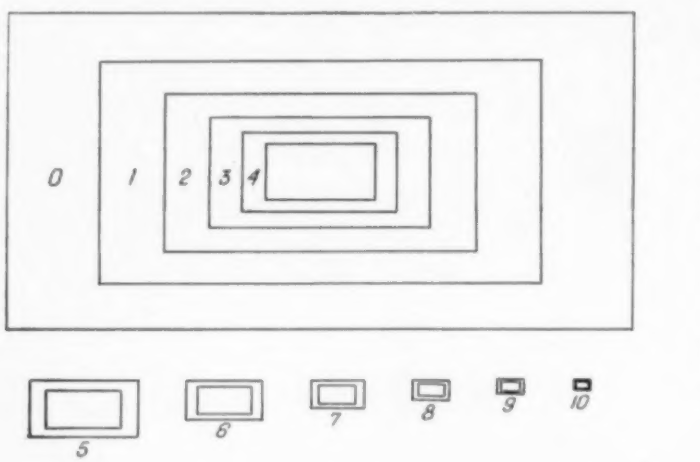
The metallurgist has a job ahead of him, too, in this revolution in raw materials. The blast furnace men should work on the problem of applying ores of lower iron-to-silicon ratios. All possible speed in these developments is needed to maintain the present rates of shipment. If it is found that fine grinding is actually necessary to the utilization of these ores, the cost of plant would be very high; one speaker predicted over $14 per ton; others said it might be much more.

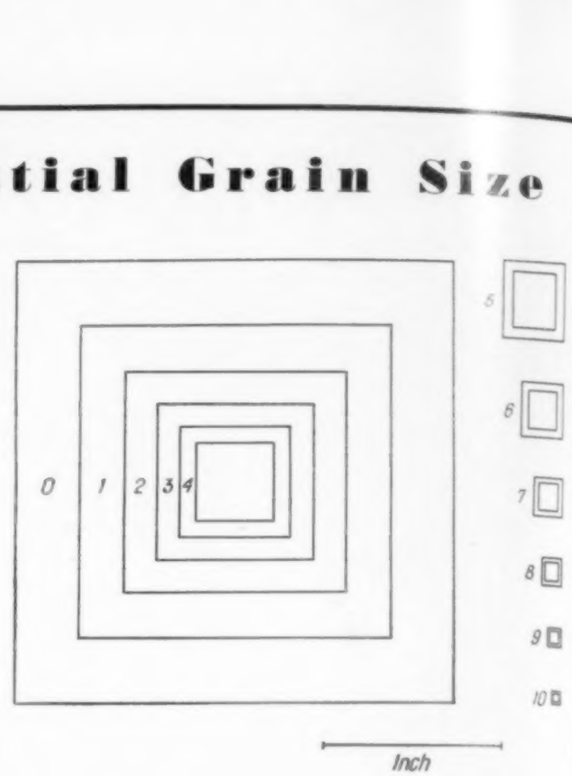
Removal of sulphur from ore by sintering has been investigated in the laboratory and sinter plant with encouraging results, particularly in removing sulphate sulphur from high-sulphur Minnesota and Michigan ores. Physical characteristics and sizing are important factors; clayey ores and particles over ¼ in. are difficult to desulphurize. In discussion it was pointed out that particles larger than ¼ in. are not efficient in regular sinter plant operation. The method seems to hold great promise for the utilization of the high-sulphur ores, and to produce, at the same time, a product that will be porous and hard enough for efficient use in the blast furnace.

Estimation of Spatial Grain Size

By William A. Johnson
Westinghouse Research Laboratories, East Pittsburgh, Pa.

(Metal Progress, *January 1946, page 87*)





Step I: Prepare a metallographic sample, etch appropriately to develop the grain boundaries, photograph at 100 diameters, and mark off an area on the print, not following the grain boundaries, which contains at least 200 grains.

Step II: Estimate the planar or W size of each grain wholly or partially in this area by using the above grids, photographed full size on transparent film. (A grain of W size 2 located at the border and two-thirds within the area would be listed under W size 2 but given a weight not of unity but 0.7.)

Step III: Figure the per cent of total area for each W size as indicated for the representative sample in Table I.

Table I — Distribution of Planar Grains

W Size	Number	Factor	Relative Area	% of Total
No. 1	9.9	×32=	316.8	18.2
2	28.3	×16=	452.8	28.5
3	56.6	× 8=	452.8	28.5
4	70.7	× 4=	282.8	17.7
5	42.4	× 2=	84.8	5.3
6+	28.3	× 1=	28.3	1.8
			Total 1618.3	

Step IV: Calculate distribution of spatial grains by volume by taking out values from Table II for proportionate planar areas. Table II shows, for example, that if 18.2% of the grains are W size 1, 25% of the volume of the specimen is occupied by spatial grains of size 1, 5.1% of the planar grains W size 2 are due to off-center intersections of these larger grains, and so on. The computation sheet below shows how these various corrections are made, step by step:

W, Planar Grain Size:	1	2	3	4	5	6 and Smaller
Area, %	18.2	28.5	28.5	17.7	5.3	1.8
	25.0	5.1	1.3	0.3	0.1	0.0
		23.4	27.2	17.4	5.2	1.8
		32.0	6.5	1.6	0.4	0.1
			20.7	15.8	4.8	1.7
			28.5	5.8	1.5	0.5
				10.0	3.3	1.2
				13.7	2.8	0.9
					0.5	0.3
Volume, %					0.7	0.2
						0.1
						0.1

Table II — Subtraction Table for Spatial Calculations

Surface Occupied by Planar Size W	Volume Occupied by Spatial Size W	Surface Occupied by Smaller Planar Size: W + 1	W + 2	W + 3	W + 4	W + 5 and Higher
1%	1.4%	0.3%	0.1%	0%	0%	0%
2	2.8	0.6	0.1	0	0	0
3	4.1	0.8	0.2	0.1	0	0
4	5.5	1.1	0.3	0.1	0	0
5	6.9	1.4	0.4	0.1	0	0
6	8.2	1.7	0.4	0.1	0	0
7	9.6	2.0	0.5	0.1	0	0
8	11.0	2.2	0.6	0.2	0	0
9	12.3	2.5	0.6	0.2	0	0
10	13.8	2.8	0.7	0.2	0.1	0
11	15.2	3.1	0.8	0.2	0.1	0
12	16.4	3.3	0.8	0.2	0.1	0
13	17.8	3.6	0.9	0.2	0.1	0
14	19.3	3.9	1.0	0.3	0.1	0
15	20.6	4.2	1.1	0.3	0.1	0
16	22.0	4.5	1.1	0.3	0.1	0
17	23.3	4.7	1.2	0.3	0.1	0
18	24.7	5.0	1.3	0.3	0.1	0
19	26.1	5.3	1.3	0.4	0.1	0
20	27.5	5.6	1.4	0.4	0.1	0
21	28.8	5.8	1.5	0.4	0.1	0
22	30.1	6.1	1.5	0.4	0.1	0
23	31.5	6.4	1.6	0.4	0.1	0
24	32.9	6.7	1.7	0.4	0.1	0
25	34.4	7.0	1.7	0.5	0.1	0.1
26	35.7	7.2	1.8	0.5	0.1	0.1
27	37.1	7.5	1.9	0.5	0.1	0.1
28	38.5	7.8	2.0	0.5	0.1	0.1
29	39.8	8.1	2.0	0.5	0.1	0.1
30	41.2	8.3	2.1	0.6	0.1	0.1
31	42.7	8.6	2.2	0.6	0.2	0.1
32	44.0	8.9	2.2	0.6	0.2	0.1
33	45.4	9.2	2.3	0.6	0.2	0.1
34	46.8	9.5	2.4	0.6	0.2	0.1
35	48.0	9.7	2.4	0.6	0.2	0.1
36	49.5	10.0	2.5	0.7	0.2	0.1
37	50.9	10.3	2.6	0.7	0.2	0.1
38	52.3	10.6	2.7	0.7	0.2	0.1
39	53.5	10.8	2.7	0.7	0.2	0.1
40	54.9	11.1	2.8	0.7	0.2	0.1
41	56.4	11.4	2.9	0.8	0.2	0.1
42	57.7	11.7	2.9	0.8	0.2	0.1
43	59.1	12.0	3.0	0.8	0.2	0.1
44	60.4	12.2	3.1	0.8	0.2	0.1
45	61.7	12.5	3.1	0.8	0.2	0.1
46	63.1	12.8	3.2	0.8	0.2	0.1
47	64.6	13.1	3.3	0.9	0.2	0.1
48	65.9	13.3	3.4	0.9	0.2	0.1
49	67.2	13.6	3.4	0.9	0.2	0.1
50	68.6	13.9	3.5	0.9	0.2	0.1
51	70.0	14.2	3.6	0.9	0.2	0.1
52	71.5	14.5	3.6	1.0	0.3	0.1
53	72.8	14.7	3.7	1.0	0.3	0.1
54	74.2	15.0	3.8	1.0	0.3	0.1
55	75.5	15.3	3.8	1.0	0.3	0.1
56	76.9	15.6	3.9	1.0	0.3	0.1
57	78.2	15.8	4.0	1.0	0.3	0.1
58	79.6	16.1	4.0	1.1	0.3	0.1
59	81.0	16.4	4.1	1.1	0.3	0.1
60	82.4	16.7	4.2	1.1	0.3	0.1
62	85.0	17.2	4.3	1.1	0.3	0.1
64	87.9	17.8	4.5	1.2	0.3	0.1
66	90.5	18.3	4.6	1.2	0.3	0.1
68	93.2	18.9	4.7	1.2	0.3	0.1
70	96.1	19.5	4.9	1.3	0.3	0.1
72	98.8	20.0	5.0	1.3	0.4	0.1

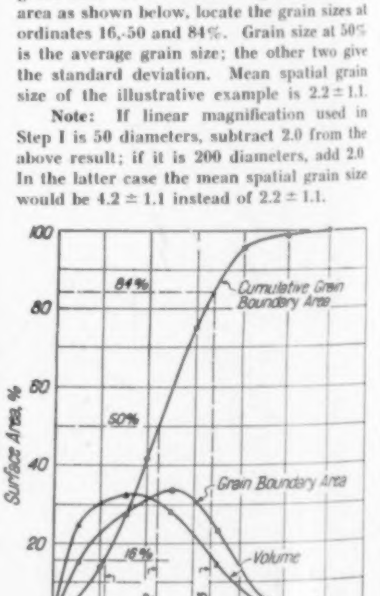
Step V: Determine the grain boundary area by the computations of Table III, starting from the percentage of spatial grain sizes by volume, just computed.

Table III — Computation of Grain Boundary Area

Spatial Grain Size	% by Volume	Factor	Grain Boundary Area: Relative	%	Cumulative %
No. 1	25.0	1.000	25.0	14.8	14.8
2	32.0	1.414	45.3	26.7	41.5
3	28.5	2.000	57.0	33.5	75.0
4	13.7	2.828	38.8	22.9	97.9
5	0.7	4.000	2.8	1.7	99.6
6	0.1	5.657	0.6	0.4	100.0
	Total relative area: 169.5				

Step VI: Determine the mean spatial grain size. Plot cumulative grain boundary area as shown below, locate the grain sizes at ordinates 16, 50 and 84%. Grain size at 50% is the average grain size; the other two give the standard deviation. Mean spatial grain size of the illustrative example is 2.2 ± 1.1.

Note: If linear magnification used in Step I is 50 diameters, subtract 2.0 from the above result; if it is 200 diameters, add 2.0. In the latter case the mean spatial grain size would be 4.2 ± 1.1 instead of 2.2 ± 1.1.



Science and Life in the World

Celebration of the George Westinghouse Centennial

Readers of Metal Progress *will have noticed, since the explosion of the atomic bombs over Japan, several articles, quotations and comments on nonmetallurgical matters — thus deviating from a rather strict editorial plan. The Editor justifies this course in his belief that science, engineering and technology have advanced more rapidly than the social structure can control them, and unless the nonengineering questions are answered correctly it will make little difference whether new technical problems are solved or not.*

It is, therefore, without apology that so much space is given in this issue to the addresses presented at the centenary celebration of George Westinghouse's birth. Seldom has a larger and more eminent audience listened to such an array of talent. Almost without exception the speakers — each a real leader in his branch of learning or engineering endeavor — emphasized the social *aspects of scientific progress. Dr. Archibald Hill, the foreign secretary of the Royal Society of England, set the keynote in his assertion that there is no universal nostrum for the world's ills, and that positive morality in the individual (with a courageous willingness to fight for the right) is the only path to safety in the forthcoming atomic age. Metallurgists, being citizens and individuals, have each one his own grave responsibility in this matter.*

Worthy of note is the fact that four times, during the Forum, proceedings were interrupted to invoke Divine guidance. Similarly we find one-quarter of the May issue of Army Ordnance Association's Preparedness Bulletin *devoted to quotations from prayers offered by Washington, Patton and Eisenhower, each humbly asking for God's help. It is at last time.*

Electric Power

The Foundation of Industrial Empire

By Charles W. Kellogg
President, Edison Electric Institute

IT IS a curious coincidence that within a six months' period fall the centennials of three great American inventors, each of whom accomplished new things with electricity, and each of whom left his name indissolubly attached to his product: "Bell" telephone, "Edison" light, "Westinghouse" electric. The force with which they all worked is thus described in words carved over a portico of the Union Station in Washington:

> "Electricity—
> Carrier of light and power
> Devourer of time and space
> Bearer of human speech over land and sea
> Greatest servant of man; itself unknown."

Electric power is the greatest achievement in the amplifying of human capability — because of the ability to transmit it to the point of use and to subdivide it into usable quantities. Today, every industrial workman in the United States has at his call the power of seven horses which, unlike the animal variety, never falter, require no time out for feeding and rest, and are so much cheaper to operate! This horsepower per man in industry is closely allied with his productiveness and real weekly wages.

To secure a background for judging Westinghouse it is necessary to describe briefly the prior achievements of Edison. Without precedent to guide him, Edison developed a low internal resist-

ance, direct-current generator for maintaining constant voltage on underground distribution lines of his own devising and — crowning achievement of all — invented the incandescent lamp, the first flameless light, which could be turned on and off at will and would run for hundreds of hours.

The original Edison plant, built on Pearl Street in New York City in 1882, and its counterparts that sprang up in many other cities, were regarded as lighting companies. They were known as Edison Electric *Illuminating* companies. With the use of electricity for power and the constantly increasing distance of the load from the central station, the industry encountered difficulties with transmission and distribution. With the relatively low voltage at which the direct current had to be generated, this meant either a fabulous investment in copper conductors or the necessity for many relatively small generating stations or both.

This dilemma was solved by George Westinghouse through the development of the alternating current system, used throughout the world today.

The problem he solved was easier stated than mastered. It required the perfecting of an alternating current generator, the design of a satisfactory transformer, adequate insulation for the high transmission voltages and the design of a satisfactory alternating-current motor. To cap the climax, alternating current brought in its train all the headaches of lagging currents and low power factors. Two other necessary details were the development of an induction meter and a machine for converting alternating to direct current for electrolytic and other processes where such current was essential.

This was a large order; but, convinced of the soundness of the principles involved, Westinghouse tackled it with characteristic vigor and system, surrounding himself with the best research brains of his time. In rapid succession the transformer was patented by Stanley in 1885, the split-phase induction motor by Tesla in 1888 and in the same year the induction meter by Shallenberger — all these members of the Westinghouse team.

In 1890, Westinghouse built a small 100-hp., single phase, alternating current plant at the mining camp of Telluride, Colo. The voltage was 3000 and the transmission distance was only three miles, but the amount of copper required was very small compared to that needed by the direct-current plant proposed by Edison in competition. The success of this plant led to the adoption of alternating current for the first Niagara Falls plant, where Westinghouse installed three 5000-hp. polyphase, alternating-current generators in 1893. These machines are the forerunners of modern hydroelectric generators of well over 100,000 hp.

Looking back now it is easy to see that, without the alternating-current system, the size and scope of our present-day electric power systems would be quite unthinkable, for the development of the years has shown the economy of generation in large stations. Equally impossible, without this basic system, would be the furnishing of metropolitan quality service to thousands of small villages and to more than 8,000,000 rural consumers throughout the country. Finally, without alternating current and the great network of transmission lines, the great production of power for the war effort would have been impossible.

The benefits to the nation are far from being confined to manufacturing industry. Electricity has revolutionized everyday life. The drudgery of wash day, the labor over a hot kitchen stove, the pumping and hauling of water, the washing of dishes can now be made easy in millions of homes. The brightening of the long dark nights, the ability to preserve food in hot weather, the health and comfort of air conditioning, all combine with innumerable labor saving devices to make electricity indeed the greatest servant of man. Without what experimenters in the late 80's called "Westinghouse current", these blessings would have been largely confined to city dwellers.

I want now to speak of George Westinghouse as a great American. Of equal value to us as a nation, if we have the sense and ability to follow it, is the example his life affords of those traits of ingenuity, self-reliance, determination and industry, which have made our nation what it is. The courage and persistence with which he followed up his vision during long years, until the soundness of his judgment was proven, were tests of true character and greatness. During this period he had to face the determined competition of the established majority in the electric service field; and the struggle was enough to daunt any but the stoutest heart. Mankind today is the beneficiary of his steadfast faith.

From the start of his inventing career he had consistently undertaken the manufacture of the products of his inventions and had made money in the process. However, the bankers of his time were unwilling to put money into what they considered an untried business without retaining a dominating position in its management. This condition seemed intolerable to the free spirit of George Westinghouse and was therefore refused; but it placed on him the burden of doing his financing from his own resources or from funds advanced without conditions by men of wealth who had confidence in him. In the last decade of his life he received a striking public recognition of his probity and integrity in his designation (along

with Grover Cleveland and Morgan O'Brien, presiding judge of New York State's highest court) as public trustee of the entire stock of the Equitable Life Assurance Society.

In commemorating the life of George Westinghouse which began 100 years ago, we express amazement at what he accomplished and gratitude for his great contribution to our common life, and we draw high inspiration from the qualities of mind and heart of this great American.

Scientific and Engineering Progress

Insurance Against Aggression and Depression

By Karl T. Compton
President, Massachusetts Institute of Technology

WHO is it that is interested and responsible in having this insurance against aggression and depression? There is fundamentally just one answer — Mr. John Q. Citizen, individually and collectively. He wants security against aggression in order that he may live his life as he wishes without outside interruption. He wants security against depression — that specter of economic disease which from time to time invades the country, and makes him the prey of circumstances over which he apparently has no control. But, individually and collectively, what can he do about it?

In order to answer this question it is necessary to look to some of the organized groups through which the collective Mr. John Q. Citizen operates, namely, his government, industry (in its two aspects of management and labor), and finally the organizations concerned with education and research which I shall call "universities".

Consider first the responsibility for insurance against aggression. Here, Mr. John Q. Citizen assigns this responsibility to his government, but we find that the responsibility for insurance against *depression* is more divided, and government, industrial management and industrial labor all share about equally. So far as I can see, the group which I have called universities is not directly contributory.

If we turn next to an analysis of the opportunities which these various groups have to provide insurance *through scientific progress* against aggression and depression, we should discriminate between *fundamental* science, in which the work is done for the primary object of securing scientific knowledge, and *applied* science in which the primary object is some device which will satisfy some human need or desire.

In the field of fundamental science I believe that past experience, future trends and the whole logic of the situation would assign priority AAA to the universities, AA to industry, A to government, and B to labor. In the field of applied science the priorities would be industry AAA, government AA, universities A, and labor B.

Finally, what can these various groups *do* to provide the implementation necessary so that scientific progress will contribute as effectively as possible to the strength and security of our country and to its industrial prosperity and high standard of living? Let me discuss the groups in alphabetical order.

The government has been active in science in two general categories — first, through its 40 or more permanent scientific bureaus, and second, through its calls for scientific assistance in times of emergency. In the latter category we find a peculiar and significant fact, namely, that the government has turned to the scientific resources of the country for help only in times of great national emergency. The record is very significant. However, there are two pieces of legislation now before Congress that show evidence of a desire to change this singular situation, namely, the one to establish an Atomic Energy Commission, and the other to establish a National Science Foundation. There is no point in my discussing them now, except to say this: The Atomic Energy Commission or its equivalent is an absolute necessity, not only for the future safety of our country, but also that the country may benefit from the future advances in nuclear science. If ever any legislation was in the "must" category, this is an example; if Congress should fail to pass adequate legislation it will be a catastrophe and a disgrace.

The legislation proposing to set up a National Science Foundation is aimed to promote progress in fundamental science in both the natural and the social fields, and also sets up a great program of scholarships or fellowships to replenish the deficiency in scientifically trained personnel created by our policies during the past war. Both for security against aggression and security against depression, replenishment of personnel is more important than laboratories or factories because, without scientists of the highest caliber, laboratories will be only a delusion and a waste of money, and factories will become obsolete.

There is just one thing about this which disturbs many scientists, namely, the danger that it may become a means of political patronage. It will require continual vigilance by high-minded citizens in order to prevent the degrading of science even a few steps down the ladder whose bottom is political patronage, log-rolling and rackets.

Industry's great role in applied science has been to seize upon promising ideas for commercial exploitation with vision and avidity and to develop them with great skill into desirable products. Their skill in effecting this transformation has been highly developed. Whereas the old motto was "from research laboratory to freight car equals seven years", the war gave many instances which could well have been stated in months!

Three new trends have come into industrial attitude toward research:

First, it has shown increasing interest in fundamental research. Most forward-looking companies engage in a certain amount that does not have an immediate practical objective because the highest type of research man cannot be retained without some work on subjects which incite his scientific curiosity, and because the directors realize that very frequently ideas come from fundamental research that have a practical application and that the company should have a small group in its own organization sufficiently informed so as to give wise advice about new developments.

Second is the undoubted fact that industrial management has become more liberal in the definition of its responsibility to its stockholders in defining the limitations of its research activities. Management realizes that its responsibility cannot adequately be discharged over a long term without vigorous support of the scientific research which provides the basis for industrial research.

Finally, the attitude of industry as regards scientific research has become notably more cooperative. This is shown in many ways, notably in the cooperation of many companies in a single field to establish and support fundamental scientific research in that field, and in contributions by individual firms either as gifts or through liberal contracts to educational or research institutes engaged in work along promising lines. In all of these instances, so far as I know, the contributing company's principal interest is to have the scientific field advanced, to be kept very promptly informed of all new developments, and to have an adequate supply of young scientists as a reservoir for future employment.

Let me turn now to the interests of labor. Traditionally labor has feared labor-saving machinery or methods. This fear receives an impetus during any depression. The long-term view, however, leads to quite different conclusions because those industries like the automobile, lamp, radio, chemical and public utilities which, through the introduction of more economical methods of production have been able to bring the cost of a product down within the reach of the average citizen's purchasing power, have thereby greatly magnified the size of the business and the total number of men employed in production, distribution, sales, and services. I believe that this fact is now generally recognized by progressive labor leaders and that, except perhaps in times of unemployment emergencies, the more progressive labor unions may be counted on to lend their support to the efforts of management.

There are, however, some areas in which intelligent action is needed. One of these is in connection with building codes. There is one general conclusion to which I know of no exceptions: Whenever any regulation or code or other obstacle in agreement or legislation stands in the way of utilizing the most advanced and improved techniques of production, or of erection and assembly, or of design, then these restrictions act to the immediate disadvantage of the public and to the ultimate disadvantage of labor.

Turn finally to some of the trends in the universities — that major source of basic new scientific knowledge. One can certainly say that scientific research is going to hold a higher place in the future, even in our engineering schools. There are emerging research "programs" built around very important objectives, requiring some special cooperative organization within the university itself. Among these may be cited the radiation laboratory in Berkeley, the four research institutes recently formed at the University of Chicago, and the electronics laboratory at Massachusetts Institute of Technology.

Now just a brief word in conclusion: It seems to me that the foregoing analysis justifies us in looking forward to the future with a considerable degree of faith and enthusiasm. We are now in an era of vigorous development both of science itself and in the techniques of organization, administration, and support, which form the proper environment for scientific progress.

Two things seem to me to be essential if we are to realize the values for security and for prosperity which can come out of this program. One is that the trends which I have described must be, by general public education, carried on with increasing understanding and support of Mr. John Q. Citizen.

The other important point is that the scientific institutions cannot prosper unless they contribute usefully to other aspects of society, and when society is in a healthy state that provides the necessary environment. These other aspects of society are most prominently before the whole world today. They involve such matters as international peace, the healing of the wounds created by the war, and the relations between management and labor. They include govern-

mental policies, such as the extent to which Mr. John Q. Citizen is to be regimented, or to which he is to retain a high degree of freedom of opportunity and initiative. They include the financial policies which can, if unwisely handled, wipe out all the reservoirs for free enterprise.

So those of us who are greatly interested in the contributions which science can make to national welfare must have also an intelligent and effective interest in these environmental aspects which not only affect the opportunities for scientific progress, but affect every aspect of our national life and individual happiness.

Planning in Science

By Vannevar Bush
Director of Office of Scientific Research and Development

UP TO THE YEARS immediately before the second World War, the contributions of science to American life had been very great indeed — directly through medicine and allied avenues, and indirectly through the provisions of a myriad of devices, instruments, machines.

In the past six years, however, a change or advance has occurred in the activities of science — a change of profound importance both for the role of science in our life and for the relation of the planning of science to other aspects of our general planning. This has taken two forms.

One may be illustrated by the way in which physicists, mathematicians, engineers, working with the Army and the Navy, demonstrated that systems hitherto used by scientists for finding out about the probable distribution of molecules in a crystal or about the phenomena of electricity could be powerful aids in determining how to seek out and sink an enemy submarine, or in ascertaining the bomber formation most desirable from the point of view of defense. More than that, they demonstrated that the best, if not the only, individuals to carry over the application of these methods to strange fields were they themselves — the scientists and engineers familiar with the methods at first hand, though at the outset entirely ignorant of the new problems.

In certain parts of the utilization of science during the past six years to supply instruments of war, another phenomenon of comparable significance occurred. It took place when the instrument or other product of scientific investigation — radar, the atomic bomb, but especially the proximity fuse — was intrinsically so complex and delicate that it either required an utterly new process of manufacture or demanded in manufacture quality and other control procedures of exceeding intricacy and rigorousness. The scientists who mastered the seemingly impossible task of initial design and development went on from that — because only they could do so — and not merely supervised but actually controlled production of the fuse at every stage from assembly of basic components all the way through to final delivery of the finished product. Thus was an older situation reversed, and production became a function of research, not research a function of production.

Call the first the successful extrapolation of some of the methods of science to problems considered outside their range. Call the second the successful translation of scientists and engineers into specialists in production and industrial techniques. When we bring the matter down to these terms these phenomena suggest to me that the contribution of science to our life is in a fair way to become more and more a direct intellectual contribution. This is not to deny that the fruits of prewar science did not grow originally out of intellectual effort. But, as we have seen in the wartime examples I have cited, such intellectual ability can be, and very effectively has been, applied to the solution of problems and the resolution of difficulties for which it is not intrinsically designed. I believe that this situation will and must be greatly extended in the years to come.

These new intellectual contributions of scientists (and engineers) will, I believe, consist primarily in an attitude toward factual data, in the effort at sharp and specific definition, in the endeavor, whatever the issue under consideration, to clear out extraneous side issues and focus attention and effort on the nub of the problem. These things are fundamental in the planning which scientists do in their own work — and I think we can agree that the planning has been pretty generally effective. They can be of equal value in other kinds of planning, particularly because much of our national planning in the future will necessarily be concerned with problems growing out of the work of science.

In our planning we may bring about serious harm if, looking upon the total industrial structure of the nation, we are misled by its great size and complexity into regarding it as essentially a matured affair, old, settled down, with its days of pioneering far in the past. Nothing could be further from the fact. The United States, it is true, is an amazingly rich and powerful nation, with industry and enterprise diversified and versatile beyond that of any other. But not even the majority of our present industry has reached the

stage where pioneering is no longer an expected part of its activity. And there lie before us a dozen new fields in which only the earliest beginnings of development have been made. The spirit and the courage of free enterprise never were more needed, never had greater opportunities than in the United States at this moment. Hence there has never been a time when it was more important for men to remember that the essence of good planning is to preserve freedom of initiative.

Our planning for science, as a part of our total national planning, must above all else foster and facilitate the creative research spirit. We have a compelling practical reason for this in the potency of applied research as a source of material benefits and full employment. We have an especially great opportunity in developing the fundamental research out of which applied research grows. The record of American applied science is a proud one; in basic research, we have not done equally well, probably partly because we had the great resources of European science on which to draw. In time to come, we must carry a larger share of the world responsibility for this.

During recent months, American national planning in science has been vigorous and active, with scientists and engineers taking the lead effectively in the long process of discussion and marshaling of evidence which is the necessary precursor to any governmental action. On the domestic front, the most notable example is the pending legislation which will bring into being a National Science Foundation, and which will therefore establish formally and firmly an active partnership between government and science.

If scientists are to take a larger part in national planning not directly concerned with science, however, there will be need for better understanding between scientists and nonscientists. They have been rather wide of the mark in their evaluations of each other. Some scientists have in all sincerity used phraseology which they would not have used had they understood its overtones in nonscientific minds. Some nonscientists have read into statements by scientists overtones that actually were not there. Each group has not a little to learn about the other, and about the innate patterns of operation which the other follows from heritage, training, and natural aptitude.

Scientists recognize research as the exploration of the unknown. The focus of its effort, then, is the *new;* its orientation is toward the future. Its so-called "laws" — its body of principles — are not laws at all, but generalizations which seek to sum up and correlate the characteristics of a large number of phenomena. Research deals primarily with external physical fact, objectively observed. When it discovers or uncovers a new phenomenon, research tends not so much to appraise that phenomenon in the light of existing so-called laws and to reject or abandon the phenomenon if it does not conform to them, but tries to bring hypothesis and theory into conformity with the new data.

Now by contrast, we recognize our government as — by tradition and by agreement — a government of laws, not of men. This is but another way of saying that the governmental system under which we operate is essentially a body of agreed abstract principles which each generation of men interprets and by which each generation of men is guided. Men to whom the art of government is a first concern, in the sense that research is a first concern to scientists, are and must be profoundly aware of and responsive to the vast accumulation of law, of precedent, of interpretation. Their orientation is greatly toward the past. They deal with external physical fact objectively observed, just as does the scientist. But they must rely upon the heritage of law and precedent. They tend to try to bring the new phenomenon into conformity with existing law — and remember that their law, both substantive and adjective, is not hypothesis nor theory, but *law,* expressing the will of the people, and to be changed only as the wisdom and the will of the people direct, and then only by processes long established and necessarily deliberate.

These are generalizations, and dangerous. Yet I believe that the scientist or engineer who sincerely desires to contribute his special skills to the resolution of public questions must recognize these as characteristics of government and must recognize that public men tend in their thinking to reflect them. To understand why these men are as they are, and why government is as it is, one must give due weight to these matters.

To conclude, then, we see before us a world of great trials, great duties, great rewards. The most precious of all the gains toward which, by earnest unselfish work, we may hope to progress is peace and good will among the nations of men. In the trials and in the duties essential to that progress, the United States must take its rightful part, must bear its full share. For it to do so, every group and calling in its infinitely varied people must give its strength of heart and mind to the common course. For us, who as scientists and engineers are familiar with special ways of thought now becoming potentially useful in new and exacting ventures, there are open opportunities greater than we have known. It behooves us, if we would serve fully, to seek understanding of ourselves and of our companions.

Horizons in Communications

By Frank B. Jewett
Vice-President, American Telephone & Telegraph Co.
President, National Academy of Sciences

IN the few minutes at my disposal the most profitable thing I can do is to devote them to electrical communications, the ones I am most familiar with, and consider mainly the horizons imposed by social and economic factors rather than the more exciting technical possibilities — fully conscious that full development of any single type of communication is not attainable without reference to developments in other forms of communication or the limitations imposed by them. As to the technical possibilities, the advances of science and technology in the last two or three decades have been so astounding that in electrical communication there is practically no limit either to the distance we know we can now go or have reasonable expectation of attaining if it is worth while to spend the necessary time, energy and money. Scientifically and technically we already know how to avail ourselves of all the elements necessary to the giving of any desired service. Some of these elements we have already developed quite fully; some are still quite embryonic. The distance further that we go technically seems to be more an economic question than a technical one.

Choice of available technological methods, when more than one is available — as wire and wireless — seems to involve basic characteristics of the transmitting medium and man's ability to manipulate it. To the extent then that engineering considerations do not govern in the future the reason will probably be found in those man-created things known as "vested interests" which we are so prone to perpetuate even when society pays quite a price for the perpetuation.

Let us look first at telegraphy — the oldest of our electrical communication services. In essence it is an expedited form of letter service, desirable when records of each transmitted message are in the hands of the correspondents.

Telegraphy is beset on all sides by competitors. Local telephony has superseded it for the great mass of short, quick communications. Even for much long distance communication where the messages are long, the telephone and cheap air mail service are serious competitors. Taking all of the factors — technical and economic — into consideration, the horizon of ordinary telegraphy seems that of a moderately expanding service in a specialized field of communication. More and more it will tend, I think, to make common use of plant facilities which must be provided in large amounts for other services.

Two-way telephony seems destined to be by far the largest factor in electrical communication, both because of its unique ability to bring distant parties together for normal ultimate conversation, and because the whole social mechanism is becoming increasingly dependent on the telephone for its efficient operation.

The goal of ideal telephone service is that of establishing connection between any two persons anywhere, anytime, without delay, on demand, and to provide them a satisfactory circuit at a reasonable charge — that is, one which will not be a deterrent to usage when such usage is desired. To a large degree this goal is already being approached in this country and at various places elsewhere in the world.

Even today there is no insurmountable scientific obstacle to a substantial achievement of the goal if other factors permit it. These other factors are essentially economic and administrative. Technology cannot furnish the whole answer, nor does its contribution seem destined to be that of some revolutionary new thing. Rather it will be through meticulous attention to the infinitude of essential items which must be associated together in the complex organism.

Aside from the transmitter and receiver, the two great problems of any telephone system are concerned with the trunk lines and with the infinitely vast and complex switching mechanism.

Because the social structure is organized as it is, with high packs of personal and business intercourse concentrated in a few hours, a peculiarly difficult problem is presented. To be satisfactory to the public any grade of service must be uniform throughout the entire day. This means that, in anything approaching the ideal, enough circuits and equipment must be provided to give no delay service at peak times. From an economic standpoint this is only possible if the costs can be reduced so that circuits and switching mechanism can be provided in great profusion without imposing a deadening load of cost on the total service.

So far as transmission circuits are concerned, the limiting factor is essentially cost of what the scientist and engineer can do.

When it comes to switching mechanisms, however, other large factors which are neither fundamentally technical nor economic are introduced. It is not inconceivable that a no-delay service for tens of millions of subscribers calling each other in wholly random fashion could be developed without aid of an operator and with full automatic registration of all data needed for

billing. The system would be so intricate, however, that it is most unlikely that the necessary information for operation could be placed in the hands of each user, or that they would be able or willing to operate such a system.

Radio broadcasting has already set the pattern for its future. Further technical developments will doubtless alter the kind of arrangement of circuits and apparatus employed, but there seems little likelihood that the basic pattern will change materially. It has become a powerful implement in the social and political life of the nation and of the world — so powerful in fact that great danger to society might easily result were it to become the tool of political government. In America it is a unique industry in that the ultimate consumer directly pays substantially no part of the cost of the service he receives. Looking to the future of its social significance, this pattern is probably the greatest insurance we have that it will not become an instrument of oppression and danger, but preservation of it will require unremitting watchfulness.

For nearly twenty years now, since long distance demonstrations showed its possibilities, television has been much discussed. So far, however, the horizons have been largely those of possibility and hope rather than those of stable service. A vast amount of technical work has been done, given added impetus by war problems. Moreover, the art, while still far from perfect, is now sufficiently advanced to forecast a system which would be technically acceptable — at least initially. Further, there is little reason to doubt but that expanding science will insure needed improvements.

Here again, therefore, the extraordinarily difficult controlling factors in creating an industry are essentially economic and commercial rather than technical. If television really does contain the germ of a great service, an obstacle to extensive employment of large screen television in theaters resides in the cheapness and speed with which motion picture films can be transported. It is not a factor where there is intense public interest in viewing at a distance actions exactly at the time they take place. It may, however, be the controlling one in economic success where true television is not employed or where synthetic programs are involved.

Likewise, since television service is tied so definitely to broadcasting and its methods, and since a sound-television set is bound to cost more than a simple loud speaking receiver, questions of the probable size and character of the audience to which the advertiser can hope to appeal become important.

Aviation, a Phase of Transportation

By Edward Warner
President of Interim Council
International Civil Aviation Organization

As I look back on the record of a war conducted so largely in the air, I can give you no guarantee that the airplane will improve the world. It will still lie in the realm of human relations to determine whether the world is to be improved; but the airplane *can* contribute mightily if it is in the hearts of its users to use it to that end. In its growth it ought indeed to be a civilizing force. It will be, if those who operate and use it and those who deal with it on behalf of governments are determined to make it so.

The airplane has two characteristics that give it value for civil use. It gives more rapid transportation, by far, than is available by any other means. It can go directly from one point to another, avoiding unfavorable terrain, and without requiring much preliminary construction.

This second characteristic of the plane as a form of transport is that it is peculiarly at the disposal of the pioneer. Operations can be started on a limited scale, almost immediately, with no more preparation than the clearing of a landing strip. It can be maintained for an amount of traffic so small that it would never justify preparation for any other form of transport. Consequently, among the social effects of the airplane, the change that it has wrought in the status of the dweller in remote places is one of the most notable.

Another of the airplane's general characteristics is that it is primarily an instrument of long-haul transportation; but the romantic appeal of intercontinental flight overshadows the more prosaic business of carrying passengers between London and Paris or New York and Pittsburgh. Yet it is between the nearby points that the largest numbers of travelers move. Other things being equal, the total volume of travel between two cities increases as the distance between them decreases. On the other hand, the *percentage* of passengers that will choose to use the airplane increases steadily with increasing length of journey from 100 up to at least 1000 miles.

As a vehicle which is not suitable for very short hauls, the airplane naturally has a larger ratio of international to domestic traffic than do other forms of transport. Whether that proportion will increase in future, and how much it will increase, will depend primarily upon whether existing annoyances and obstacles continue. It is a

strange anomaly that 40 years ago the crossing of the Atlantic needed a week at best, but the preparation for the trip took no longer than was required to pack a suitcase, call a travel agency for a ticket, and write a check in payment; whereas at the present time the Atlantic can be crossed in less than 12 hr., but it is a very fortunate traveler who can make his way through the preliminary barricades of passport and visa requirements, of tax certificates and currency authorizations and the like, in less than a week!

If the international contest in developing air transportation is to work for good, it must fit certain specifications. It must not provide the occasion of political or economic pressure of the strong upon the weak. It must not admit of purely restrictive and negative attitudes, holding the aerial passer-by for ransom. It must avoid discrimination between nations. It must hold the door of opportunity open to all. It must provide checks to unfair or destructive competition.

Sovereign states now have the right to bar one another's aircraft unconditionally from their air space. They have the right to prohibit the transport planes of others from even passing briefly through their skies without touching the ground. To exercise that right, or to claim a price for passage, would be a selfishly restrictive exploitation of geographical position. It would fill the victims with an enduring sense of outrage. Yet the exchange of air commerce is now subject to special arrangements between the states, two-by-two, and in these negotiations it is almost impossible to avoid political or economic pressures to gain special concessions.

The world wants the highest quality of air transport service; it wants such services to be in ample supply, maintaining direct and convenient connections among all the parts of the world. It wants services which all may use; and in the provision of which all will have an honest chance.

I have spoken first on some of the political and administrative problems which international flight has created because they seem most significant in determining the effect of air transport upon the quality of civilization, and because the problems of aircraft design, insofar as they have determined the quality of service rendered, have been solved. I do not mean there will be no further improvement in the airplane but it will produce no fundamental change in the *kind* of service; we already have a vehicle which is capable of going anywhere.

In the technology of airline *operation*, on the other hand, critical problems still await solutions which would permit fundamental changes in their character. The realms of air navigation and air traffic control present even more urgent demands for invention of revolutionary character. The greatest advance that can be made is not in speed, or even in economy, important as that is, but in regularity. When cancellations on account of weather are reduced to a tenth of their present number, air transport's whole status will be changed. Thanks to wartime development in radio and radar, and to improved means of preventing ice formation on the airplane, we now know how that change is to be made, but the greatest need of the near future is to take the necessary administrative decisions and to make the necessary installations of equipment so that aircraft can be operated freely on world-wide routes, with assurance that the same types of navigational aid will be available to them everywhere and that the same indications on the same instruments on the board in front of the pilot or navigator will mean the same thing everywhere.

Despite the passage of 15 years since radio aids to instrument landing were first demonstrated, there has not been a single installation of instrument landing equipment in North America for routine use in civil transport. Our radio approach methods are only designed to bring the pilot to the edge of the airport; from there on he must see his way. Yet during the war it was demonstrated that under military conditions regularity of service can be maintained in all weather and zero ceiling except during the heaviest icing conditions and violent thunderstorms.

Another problem that awaits solution by radio and radar experts will grow more pressing. That is the problem of air traffic control, which is now handled by a person on the ground who must visualize the traffic pattern for his area. The scheme is workable only if aircraft are kept separated by distances enormously larger than would be needed for safety if the directed pilots were always in direct visual contact with one another. The ultimate answer to the traffic control problem must include something in the nature of a search radar in the aircraft which will give the pilot enough information about the position of neighboring aircraft so that he can shape his own course when flying on instruments with a close approach to the ease and certainty that he would enjoy in perfect visibility.

Looking back on the past 25 years of air transport development no one could doubt the future. New developments will take place; new inventions will be made. Step by step the quality of air transport service will improve, and it will become more reliable and more economical. It will assume increasing status as a major element in the world's transportation system.

The Future of Atomic Energy

Atomic Explosives

By J. Robert Oppenheimer
Formerly, Director of Los Alamos Laboratory
of Manhattan Engineer District

THIS PHASE of the subject, if not the most entertaining, is at least the most important. I cannot tell you of the probable future technical developments of atomic explosives, for when the war was over we recognized that we had only scratched the surface of this problem. But there is only one future of atomic explosives that I can regard with any enthusiasm — that they should never be used in war. Since in any major total war, such as we have known lately, they *will* most certainly be used, there is nothing modest in this hope for the future: It is that there be no such wars again!

Some months ago, a group of us, acting as consultants to the Secretary of State, spent many weeks exploring this problem. We recommended the formation of an International Atomic Development Authority* entrusted with the research, development, and exploitation of the peaceful applications of atomic energy, and the elimination from national armaments of atomic weapons.

In this proposal we attempted to put into a constructive context two sets of facts, long recognized. The first of these is that the science, the technology, the industrial development involved in the so-called beneficial uses of atomic energy are inextricably intertwined with those involved in making atomic weapons. The same raw material, the plants of an atomic power program, the various fissionable materials derived from uranium and thorium, the same physics which must be learned and studied and extended in the one field will help with the other (although there are of course some things in the higher art of bomb-making that as yet appear to have no other application).

Thus a mere prohibition on the activities of nations in the field of atomic energy sufficiently incisive to prevent rapid conversion to atomic armament would at the same time close this field to the national exploitation of any of its benefits. This fact, which further technical developments appear unlikely to invalidate, has long been regarded as an almost decisive difficulty on the path of international control. It might have appeared so to us too, if there had not been a greater one, for we are still faced with the fact that there exists in the world today no machinery for making effective a prohibition against the national development of atomic weapons. In the light of this fact, that to my mind touches upon the heart of the problem, the close technical parallelism and interrelation of the peaceful and the military applications of atomic energy cease to be a difficulty, and become a help. This does not, unfortunately, mean that they guarantee a solution. But it does mean that they provide a basis for seeking a healthy solution that would not otherwise exist.

If there were nothing to do with atomic energy but make bombs, there might still, it is true, be a convention between nations *not* to do so, and two proposals have been current for supplementing such an international convention with some form of international action. One of these would set up a scheme of inspection, whose sole function would be to attempt to establish that the convention was in fact being observed. I doubt whether the relations between this agency and the nations and nationals whom it was instructed to police would be such as to diminish the nationalism leading to war, or to inspire the confidence of the nations in each other, or to advance the cause of the unification of the world, or to serve as a useful prototype for the elimination of weapons of mass destruction perhaps equally, perhaps more, terrible.

The second suggestion for international action to supplement the renunciation by nations of atomic armaments has a more affirmative character. It is that an international agency be entrusted with the making of atomic weapons. This has two weaknesses, and probably fatal ones. The more serious is that there is nothing that an international agency can do, or should do, with such weapons. They are not police weapons. The second difficulty, desperately acute, is that such stocks of atomic weapons, however earnestly they are proclaimed international, however ingeniously they are distributed on earth, would nonetheless offer the most terrible temptation to national seizure for the almost immediate military advantage that their use might afford.

Therefore it is time to turn to the second of the great difficulties that have from the outset been regarded as preventing any effective international control — the absence in the world today of any machinery adequate to provide such control, any precedent for such machinery, any adequate pat-

*Outlined in *Metal Progress* for May, page 992.

terns of the past to provide such precedent. Just this is the reason why the problem is so much of a challenge, why we may be sustained by the hope that its solution would provide such precedent, such patterns, for a wider application. It did not take atomic weapons to make wars, to make wars terrible, to make wars fatal.

But the atomic bomb, most spectacular of proven weapons, most inextricably intertwined with constructive developments, least fettered by private or by vested interest or long national tradition, has to many seemed the place to start.

Many have said that without world government there could be no permanent peace, that without peace there would be atomic warfare. I think one must agree with this. Many have said that there could be no outlawry of weapons and no prevention of war unless international law could apply to the citizens of nations, as federal law does to those of states. I think one must agree. Many have said that atomic energy could not be controlled if the controlling authority could be halted by a veto. I think one must agree with that too. However, with those who argue that these things are directly possible, in their full and ultimately necessary scope, it may be rather difficult to agree. Now the proposal of the State Department's board of consultants is that *in the field of atomic energy* there be set up a world government, that in this field there be renunciation of national sovereignty, that in this field there be no legal veto power, that in this field there be international law.

How is this possible, in a world of sovereign nations?

There are only two ways in which this ever can be possible: One is conquest — that destroys sovereignty; the other is the partial renunciation of that sovereignty.

Whatever else happens, there is likely to be a discussion of the control of atomic energy in the United Nations. Should these discussions eventuate in the proposal of an International Authority, these proposals would be presented for ratification to the several nations. Each nation, the small as well as the great, can exercise its sovereign right to refuse such ratification. Should that happen, there would be no Atomic Development Authority, and conceivably (in my opinion, probably) no trustworthy international control of atomic energy. But if it comes into existence, and insofar as it stays in existence, it will provide, in the field of atomic energy, the international sovereignty whose necessity has been so generally recognized.

Its coming into existence will be a step that, once learned, can be repeated; a commitment that, once made in one field, can be extended to others. This would not be possible if there were nothing of value to do with atomic energy, if the prevention of atomic armament were its only concern, if all other activity were technically so separable and separate from atomic armament that it could remain in national hands. In the long struggle to find a way of reconciling national and international sovereignty, the peaceful applications of atomic energy can only be a help. It is perhaps doubtful that we should have had a federal government had not those functions that could not safely nor effectively be carried out by the States had a certain importance for the people of this country.

No thoughtful man can look to the future with complete assurance that the world will not again be ravaged by war, by a total war in which atomic weapons contribute their part to the ultimate wreck of our western civilization. My own view is that the development of these weapons can make, if wisely handled, the problem of preventing war not more hopeless, but more hopeful than it would otherwise have been, and that this is so not merely because it intensifies the urgency of our hopes, but because it provides new and healthy avenues of approach.

If we are clear on this, we shall have some guide for the future.

Nuclear Power

By Enrico Fermi
Professor of Physics, University of Chicago

THE ATTENTION of the public in the problems of atomic energy has been centered so far primarily on the military side of the development. There are, however, a number of possibilities for the peacetime uses of atomic energy which in the long run may prove more important than the bomb. Speculation along these lines, of course, can be only very sketchy, as difficult as it would have been one century ago to guess the development of electricity.

Chain reacting "piles", in which energy is produced at an easily controllable rate,* have been operated for over three years. Starting with the first pile, which was run only up to 200 watts, the power has been stepped up in successive units by enormous factors. The piles operated at Hanford, Wash., for the synthesis of plutonium produce

*Dr. Fermi's brief exposition of the neutron reactions and the control of "piles" is omitted; these points were clearly presented in R. P. Johnson's condensation of the "Smyth Report" printed in *Metal Progress* last December.

energy in amounts comparable to that of the largest hydroelectric plants. However, the energy that is produced in the piles built until now is delivered at such a low temperature that it is of no practical use. In the Hanford plants it actually is wasted for the extremely unconstructive purpose of heating, by a small amount, the waters of the Columbia River.

The chief technical difficulty which stands at present in the way of production of atomic energy for practical uses is this very fact, that in all the reacting units that have been constructed the energy is produced at a very low temperature. This undoubtedly is due to a great extent to the fact that their primary purpose was not production of useful power but the production of plutonium. But there is no known practical limitation to the temperature at which energy can be produced by a fission chain reaction. Indeed there is reason to believe that in the explosion of the atomic bombs temperatures perhaps as high as 1,000,000° C. may have been obtained.

For machines designed to operate at a steady level a practical limitation is imposed by the refractory properties of the materials used. In this respect, the choice of the materials is quite critical because not only their ability to stand high temperatures must be taken into account but also one must consider the adverse effect that foreign materials may have on the nuclear reaction itself, since most materials absorb neutrons. When this absorption is large the heat production stops.

It has been mentioned that the essential fuel in piles of the Hanford type is U^{235} which represents only 0.7% of the total weight of natural uranium. The content in fission energy of uranium is roughly 3,000,000 times that of an equal weight of coal. If only 0.7% of the uranium is utilized, the practical ratio will be about 20,000. These figures point to the importance of devising methods for the complete utilization of the energy of uranium. This may not be very pressing since there still are fairly large uranium deposits which can be mined at relatively low cost.

On the other hand the energy value of one pound of uranium is so great that even an enormous increase of cost of this material may not interfere with its economical use as a source of power. Indeed 3,000,000 tons of coal, equivalent in energy content to one ton of uranium, cost about $8,000,000. Consequently, as far as cost of the raw materials, uranium and coal would become equivalent for a price of uranium of $4000 per lb. Before the war the cost of uranium was about $2 per lb.

We might conceive that 20 or 30 years from now the general scheme of atomic energy production may be perhaps about as follows: There will be large central installations in which very great amounts of power will be produced and transformed into electrical energy or steam for local power consumption. Besides producing directly power, these large units may also produce some amount of plutonium which will be extracted and distributed to small installations in which plutonium and not uranium will be used as the primary fuel. This plan would have the advantage of permitting wide use of relatively small power units, thereby reducing very greatly the difficulties of electrical distribution.

However, there is no denying the fact that the possible use of plutonium for aggressive warfare constitutes a difficulty for the industrial uses of atomic energy that is much greater than any technical difficulty that we can foresee. The problem of preventing this use is essentially political and not technical, and I do not see much hope of solving it unless the very basis of the relationships among nations should be thoroughly changed in the future years.

One more characteristic of atomic energy units will prove a serious limitation to their general use. That is the necessity to shield the pile with such materials as to prevent the escape of lethal radiations. This will prevent several uses of atomic power. It does not appear possible, for instance, to design an atomic power unit light enough to be used in an automobile or in a plane of ordinary size. Perhaps a large locomotive may be the smallest mobile unit in which an atomic power plant conceivably could be installed.

We may summarize this discussion by stating that there is definitely a technical possibility that atomic power may gradually develop into one of the principal sources of useful power. If this expectation will prove correct, great advantages can be expected to come from the fact that the weight of the fuel is almost negligible. This feature may be particularly valuable for making power available to regions of difficult access and far from deposits of coal. It also may prove a great asset in mobile power units — for example, in a power plant for ship propulsion.

But the chief obstacle in the way of developing atomic power will be the difficulty of organizing a large scale industrial development in an internationally safe way. One might be led to question whether the scientists acted wisely in presenting the statesmen of the world with this appalling new problem. Actually there was no choice. Once basic knowledge is acquired any attempt at preventing its fruition would be as futile as hoping to stop the earth from revolving around the sun by decree.

Radioactive Isotopes for Diagnosis and Cure of Disease

By W. Edward Chamberlain
Professor of Roentgenology and Radiology
Temple University School of Medicine

FIFTY YEARS AGO, on March 1, 1896, Becquerel discovered the radioactivity of uranium. This appears to have been man's initial exploration in the field that occupies our attention at this time. By 1898 the Curies had discovered radium. Soon the biologic implications of atomic energy became apparent through injuries to Becquerel and other workers. Evidence soon accumulated that the rays from radium, along with those from X-ray tubes, could be used with benefit in the treatment of cancer and a number of other diseases. Thus the earliest application of atomic energy to biology* lay in the field of treatment.

The ever accelerating advance of science exhibits some very human facets; it even follows cycles that might be stigmatized as fashions! A good example is to be found in the influence which Sir William Osler still wields over the medical world. Osler's system of teaching and practicing medicine, and his approach to clinical research, were emphatically based upon the autopsy. He who successfully foretold the autopsy findings, scored 100 per cent!

But how refreshing is the recent shift of emphasis from Osler's morphology to where we begin to uncover disease at a stage when it is still curable! And from the standpoint of scientific interest there is no comparison. The new science of atomic energy will benefit biology and medicine not only directly, as when radioactive isotopes from cyclotron, betatron or chain reaction pile are put to work as tracers, or as therapeutic agents, but indirectly, through the spectacular advances which it has produced and will continue to produce in all scientific thinking.

At this point it might be well to glance over some outstanding recent examples of radioactive tracer technique in biology. When radioactive isotopes of iodine became available, doors opened in all directions in the study of diseases of the thyroid gland. For example, a patient with clinical evidence that the thyroid gland is supplying hormone at an abnormally high rate may be fed a minute dose (0.1 microgram) of radioactive sodium iodide. If then a Geiger counter is applied over the skin of the patient's neck, the rate at which the iodine becomes concentrated in the thyroid gland can be determined with remarkable and entirely adequate accuracy. Cases have already come to light where this technique, giving negative results, has shown that the patient's trouble is produced by some gland other than the thyroid, as supposed.

Radioactive iodine is also particularly informative when used in another very valuable technique, the so-called "radio-autograph". After having received a suitable dose of radioactive iodine, bits of thyroid tissue are sectioned and held in close contact with a photographic film. The developed film and the sectioned tissue are then studied microscopically. By comparing the microscopic sections and the radio-autograph films at identical magnifications, it is possible to determine just which elements in the gland structure have taken up the iodine, for the microscope reveals the location of the film blackening that was caused by the radioactivity. In cases of cancer of the thyroid, the method is particularly valuable in that it may be a guide to treatment.

The value of radioactive isotopes is that they mingle with the stable element without altering the physiology of the patient in any discernible way, and that very minute amounts need be used (one part in ten billion for sodium in salt). Of the hundreds known, relatively few are available as biological tracers, either because they disintegrate too rapidly, they are not involved in biological processes, are not available in sufficient abundance, or release inadequate energy for detection. However, it would be difficult to overemphasize the advantage of the tracer techniques.

Radioactive iron has brought us important new knowledge on the red blood cell; sodium is used for studies of circulatory time and efficiency and of the function of membranes in the gastrointestinal tract; carbon has given startling information about functions of the liver; calcium and strontium in studies of bone metabolism.

*EDITOR'S NOTE — A complete afternoon's program was devoted to recent advances of radiology in biological science. CORNELIS B. VAN NIEL, professor of microbiology at Stanford University, speaking on the subject "Light and Life — Photosynthesis" showed how the use of radioactive tracers has thrown an entirely new light on the reaction between H_2O and CO_2 that is catalyzed by chlorophyl. All previous work had been done on the assumption that the oxygen released by this reaction came from the CO_2; as a matter of fact it comes from the water. GEORGE W. BEADLE, professor of biology at Stanford University, described his experiments on genes; since there are so many different kinds of these giant molecules, indistinguishable by ordinary tests, he has made use of the technique of radiating a sample, thus killing its self-duplicating ability, and then putting portions of it into various cultures and studying the reactions or lack of reaction — thus finding out at least what the dead gene should have done.

Of all tracer substances the one that stands out as the most useful and interesting for the biologist is radioactive phosphorus. Phosphorus plays an essential part in the metabolism of all living cells, in the plant world as well as in animals. It tends to become concentrated in an organism wherever growth and formation of new cells are most active.

This gives it important implications for cancer research and cancer therapy. In this by-product of atomic energy we are on fairly familiar ground, for the ionizing radiations from natural radioactive sources such as radium and radon have been used in treatment for nearly 50 years and we have accumulated a great deal of experience in this field. Based upon this experience, certain conclusions may be drawn with a fair degree of certainty.

Also, based on experience, we need to be warned against over-optimism. Cancer has been cured by irradiation in many thousands of cases and the percentage of such good results has increased steadily throughout the years. This improvement has been due in small part to improvements in equipment, in large part to increased knowledge and skill of the radiologist. With some caution, then, let us look at certain exciting and intriguing aspects of our subject.

Radioactive isotopes of iodine were at once proposed for thyroid cancer. Radioactive phosphorus and sodium have been administered in some hundreds of cases of leukemia (excessive proportion of white corpuscles in the blood), and somewhat indiscriminately in cancer of many cell-types and different anatomic distributions. Some work has been done in the treatment of bone tumors with radioactive calcium and strontium.

In the main the results have been disappointing. The reason may not be far to seek, and may be illustrated by phosphorus.

Cells that are multiplying rapidly display an appetite for phosphorus that is something to marvel at — and to take advantage of. But the difficulty seems to be that certain essential, normal cellular components of the body share this appetite, and when enough P^{32} is administered to put an end to the tumor we are in danger of seeing also the end of the patient! Even where the bone tumor is unusually radiosensitive, the blood forming organs are likely to be equally sensitive. A dose that is safe for the red bone marrow will probably fail to cure the tumor. Unfortunately, on the other hand, a dose that is adequate for cure of the tumor may cause the death of the patient in the process.

In acute forms of leukemia nothing seems to benefit the patient. But for many years X-ray therapy has been found valuable as a palliative agent in chronic forms of this disease; P^{32} is apparently at least as efficacious as X-ray therapy, and exhibits a number of advantages from a technical standpoint.

The one disease in which P^{32} has already established itself as the best available remedy is polycythemia vera. This is a disease in which the bone marrow puts out too many red blood corpuscles and the circulating blood becomes too thick to flow normally through the capillaries. When a patient with this condition is given P^{32}, the radioactive material goes right where it will do the most good and the bone marrow begins to behave better.

Other byproducts of the physicist's nuclear researches are yet to be explored. The biological effects of the beam of fast neutrons from a cyclotron are measurably different from those of X-ray beams. Possible therapeutic applications of slow neutrons are being looked for. In these, as in all cases, therapy with radiations is a two-edged sword, and should be used only by people with adequate experience. The sum total of human misery that has already been caused by X-ray and radium is enough to give one pause, especially as almost every bit of it could have been avoided.

Attempts to foretell the future of atomic energy require courage, if not foolhardiness. Nevertheless a few things seem to stand out rather boldly as we look at the record. From the point of view of biology and medicine, a truly brilliant future can be predicted for atomic energy, provided its potentialities as an explosive do not lead to the total destruction of our civilization.

The extraordinary achievement of the Manhattan District's scientists was a result of tremendous and beautifully coordinated effort for which the whole nation shares the credit. Why should we not embark upon another tremendous and coordinated effort, designed to solve certain pressing questions in human relations? If the greatest of physicists, chemists and engineers can be brought together for the bomb that made a place in history, why cannot the greatest men in the fields of psychology, psychiatry, human history and social techniques be similarly brought together? With God's help, man's inhumanity to man might turn out to have been a curable disease!

Isotopes in Chemistry and Metallurgy

By Hugh S. Taylor
Dean of Graduate School, Princeton University

THE MANTLE of the prophet sits uncomfortably on the shoulders of the scientist. We are all familiar with the physicists of the early 1890's and their belief that there was no further future for physics than the determination of additional decimal places in the data of physics then known. Nor would the scientist speaking of the postwar future of science in 1919 or 1920 ever have forecast the tremendous advances that the last decade has revealed. All that one can hope to accomplish, therefore, in taking up such a task after World War II is to trace the evolution of one's own area of science in the immediate past and venture a short extrapolation into the years immediately ahead. This then is my apology in advance for what of novelty there is lacking in what will follow.

The curve of progress in chemistry that we need to chart for extrapolation into the years immediately ahead is itself relatively brief. It dates in essence from the discovery by Urey in 1931 of the heavy isotope of hydrogen and the swift translation of that discovery into the separation of these two isotopes. That achievement made it possible for the chemist to formulate the problems that he could bring to solution with the aid of isotopic nuclei and that hitherto had escaped his techniques of measurement. The isotope has become the chemist's messenger boy in journeys of discovery which without the isotope were impracticable. The years following Urey's discovery of heavy hydrogen were rich in yield of isotopic products with which to venture into this virgin field. Thus, by 1940, the scientist was aware of the existence of 277 stable isotopes and nine of the naturally occurring radioelements. There were in addition 370 known in which the product nucleus was not stable but undergoes further radioactive change.

Prior to the war effort only the stable isotopes of hydrogen, of carbon and of nitrogen had been separated on anything more than the gram scale. Electrolysis had permitted the production of heavy water by the kilogram and the exchange reactions developed by Urey for carbon, nitrogen and sulphur had indicated the possibility of commercial production of the stable isotopes of these elements.

The war effort transformed our concepts of isotope separation. We demonstrated that electrolysis of water, coupled with a suitable chemical exchange reaction between the effluent hydrogen and inflowing water, could be used to produce heavy water in tonnage quantities as a byproduct in any large-scale electrolytic hydrogen-oxygen unit. More significant, however, was the demonstration that isotope separation could also be achieved on a plant scale at the opposite end of the periodic table, in the separation of the U^{235} and U^{238} isotopes whether by simple diffusion through membranes, thermal diffusion, or by the mass spectrographic technique.

The significance of these achievements may thus be summarized: The large-scale separation of the stable isotopes of hydrogen and uranium, representing the simplest and most difficult cases, has now been achieved. The large-scale separation, therefore, of any intermediate stable isotopes in the periodic system can be reduced to practice whenever the necessity for such is indicated. Separation of the stable isotopes becomes thus a standard manufacturing technique.

[Dr. Taylor then described the notation used by the physical chemist to describe the nuclear reactions and classified the various known types. These matters were adequately presented in the "Smythe Report", summarized in last December's *Metal Progress.*]

The processes known in 1940 included bombardments of atoms by neutrons yielding alpha particles, protons, gamma rays, or two neutrons. Also known in 1940 were a series of nuclear reactions in which neutrons were produced by bombarding nuclei with protons, deuterons and alpha particles. There appears to be no reason why the reverse processes should not occur. Indeed, with the sources of neutrons in high concentration that nuclear fission provides, we may expect to record all these processes of change; they may already have been achieved. When the data are in, it is certain that the chemist will have at his disposal many more than the 370 radioactive isotopes of the 92 elements that he knew of in 1940. The larger the range of his knowledge in this area the better equipped will he be to master the details of nuclear structure and its stability.

In what areas of chemical science will all these isotopes, stable and radioactive, provide new tools for study and research?

Disputed mechanisms can now receive decisive tests in chemically homogeneous systems as well as in reactions at surfaces. For example, our knowledge of mechanism in ammonia synthesis is already more certain with studies of heavy hydrogen and heavy nitrogen exchange on catalyst surfaces. Experiments with heavy hydrogen have given much information about the role of catalysts in the various transformations of the hydrocarbons. There are great divergencies in catalysts with respect to their ability to break carbon-carbon bonds, and it is such knowledge which governs the

choice of suitable agents in the gasoline and liquid fuel industries. A company manufacturing gasoline has already undertaken the industrial production of heavy carbon, C^{13}, the stable isotope — while C^{14}, the long-lived radioactive carbon with a decay period of more than 1000 years, is promised as a byproduct of the uranium pile.

The availability of radioactive isotopes from the nuclear reactions in the uranium pile will increase the utilization of tracer techniques in the area of metallurgy and metallography. Metallurgical techniques frequently involve reactions between solids and gases, and it is precisely this area of chemical kinetics that has been the least penetratingly studied by scientists. Tracer techniques have an immediate applicability to such heterogeneous reaction processes, and the uranium pile (since it is capable of yielding generous quantities of radioactive metals in all areas of the periodic table from light to heavy metals) will notably assist in the prosecution of such studies.

Similarly, in the metallography of pure metal and alloy structures the utility of radioactive tracers will help to solve such problems as grain growth, diffusion through lattices and along crystal boundaries, alloy structures and superlattices. Here is a rich field for future work.

In analytical chemistry the radioactive tracers may be expected to find service in speeding up the routine analysis of industrial products and intermediates. Development of automatic and recording methods based on the measurement of the radiation emitted is at once obvious; active progress in this area is already underway.

Problems of fluid flow in industrial operations will be immensely aided in their solution by the availability of isotopes both stable and radioactive. Already, as a byproduct of the atomic energy war effort, the whole problem of vacuum technique on an industrial scale has been immensely assisted. It is now known that huge plants can be assembled which can operate at low pressures with a complete freedom from leaks. The discovery of leaks by means of a probe gas, using rugged industrial mass spectrographs and semiskilled operators, is recorded by P. C. Keith in his account of the role of the process engineer in the atomic bomb project. By injecting radioactive tracers into any moving mass of fluid the pathways which the fluid takes and the relative distributions through several paths can be continuously measured and recorded.

The history of science reveals that after each major advance in devising new tools for experiment, the progress of the science develops at a swift pace while the new applications are explored in their many possibilities. We are in such an area of progress today, and especially to the younger scientists is this a golden opportunity. To them we can address the words attributed to Tycho Brahe:

> "Take thou the splendor, carry it out of sight
> Into the great age I must not know,
> Into the great new realm I must not tread."

Peacetime Implications of Biological Warfare

By George W. Merck
President, Merck & Co., Inc., Rahway, N. J.

BIOLOGICAL warfare, as its name indicates, involves the use of germs against human beings, plant and animal life. As it has been developed in this country, it includes the use of synthetic agents to destroy or distort plant life.

It is not new; it was employed on a limited scale in World War I. It has now advanced sufficiently to be considered a "threat in being" of equal importance to gas warfare. It must be given careful and serious consideration in whatever deliberations take place concerning the implementation of a lasting peace in the world, for the known potentialities of this type of warfare cannot be ignored.

In the fall of 1941 a special committee of biological scientists reported as follows to the Secretary of War:

> "The value of biological warfare will be a debatable question until it has been clearly proven or disproven by experience. The wise assumption is that any method which appears to offer advantages to a nation at war will be vigorously employed by that nation. There is but one logical course to pursue, namely, to study the possibilities of such warfare from every angle, make every preparation for reducing its effectiveness, and thereby reduce the likelihood of its use."

These objectives were obtained by a combined organization in which the Army, the Navy, and civilian scientists (in and out of uniform), universities, private research institutions, industries, and several departments of the Government worked together with allied teams in a most effective manner. At the height of its development, this Special Projects Division of the Chemical Warfare Service of the Army, which carried the main responsibility for the biological warfare program, had a personnel of 3900. Of these some 2800 were Army per-

sonnel, approximately 1000 Navy, and about 100 civilian. In addition, the Navy had a separate group of nearly 100 at work. This group of men and women deserve highest praise. They subjected themselves, month after month, to risks and dangers such that experienced physicians and bacteriologists visiting the experiment station would stand aghast when they realized what was going on about them. Their sighs of relief when they left the secured areas were not put on, I assure you.

While the main objective in all these endeavors was to develop methods for defending ourselves against possible enemy use of biological warfare, it was necessary to investigate offensive possibilities in order to learn what measures could be used for defense. Accordingly, the problems of offense and defense were closely interwoven in all the investigations conducted. Consideration of the problem from an offensive point of view necessitated numerous new developments and concepts.

In general terms, the following is a brief list of the chief accomplishments:

1. Development of methods and facilities for the mass production of numbers of virulent micro-organisms, and the discovery of means for protecting men, animals and plants from them.
2. Development of methods for rapid and accurate detection of minute quantities of disease-producing agents.
3. Study of air-borne disease-producers.
4. For the first time a pure, crystalline, bacterial toxin was isolated and studied — the toxin of clostridium botulinum, the most potent biological poison known.
5. Development of vaccines to protect chickens against two highly fatal diseases — "Newcastle disease" and "fowl plague".
6. A successful vaccine against "rinderpest", a highly fatal disease of cattle, capable of being produced in huge quantities. It is already available for countries where this disease has been a crippling plague of livestock.
7. Intensive study of fungus, bacterial and virus diseases of crop plants, and their control.
8. Study of more than 1000 chemical agents on living plants.

The latter is a particularly fertile field and one that promises much to agriculture in the sectors of weed killers and selective agents for plant control. The work was initiated to find destructive agents against various crops and was successful. Only the rapid ending of the war prevented field trials in an active theater of synthetic agents which would, without injury to human or animal life*, affect the growing crops and make them useless.

Applications of certain of these agents, even in infinitesimal dilution, had shown that they were capable of depriving the enemy of the benefits of his own labor by depriving his garden and field crops of their fruits. Not until he had carried through the labors of cultivation would he find that the roots had grown sere and that the plant must wither away without yield.

The scientists in charge of this work are leaders in their fields, as were all the scientists in charge of the various projects. As to its peacetime implications, they have stated that eventually any living plant process may be brought under control through critical use of some growth regulating substance. This means that every agricultural or horticultural practice which affects growth, development, ripening or storage can be influenced to economic advantage.

The pattern of the plant projects is no different from the general form of the entire biological warfare program or its other divisions, the animal and the human. It is obvious in all of them that there cannot help but be important advances in knowledge, many of them fundamental, and gains in scientific achievement — many of them capable of practical application. In fact, it is quite impossible for work to be done in this field without such results. It is inherent in the nature of the work. It has a guarantee of good — economic advantages in agriculture, parallel gains in animal husbandry, and above all, vital contributions to the fight against human suffering.

Prediction of the results of scientific inquiry is not easy; neither is it safe. There are too many "ifs". But most of these "ifs" grow out of the almost universal practice of research workers to indulge in what Horace Walpole called "serendipity". You perhaps recall his story of the three princes of Serendip who would, faring forth on an errand, never return with what they sought but they always found something of greater value.

Pasteur stated the same idea in a different way when he said: "It is characteristic of science and of progress that they continually open new fields to our vision; in scientific investigation, chance favors the trained mind."

A knowledge of the achievements of this Special Projects Division (whose activities will be continued under the National Academy of Sciences) emphasizes several of its peacetime implications. For example, the work on rinderpest resulted in building up an adequate defense. It has made that particular agent impotent as a weapon in biological warfare.

One might give a thought to this paradox: In order to perfect the weapon, we perfected the defense, thereby destroying the weapon. Would that such an ideal pattern could be applied to all aspects of warfare!

*Editor's Note — The speaker did not explain why it is regarded as more humane to starve your enemy than to poison him.

The Social Composition of Scientific Power

By Isaiah Bowman
President, Johns Hopkins University

EACH generation rediscovers that a man's desires include the compulsion to seek things beyond raw "freedom" and to create the social organisms of family and group. Each step on that long road of seeking and of creating diminishes the "freedom" with which he began. During the past century we have moved into a time of complex servitudes, or restraints upon freedom imposed by the larger and higher national "community" and its evolving policy. For 25 years we have had a parallel upsurge of social ideas, many of them in sharp conflict with others, that are proving far more potent than machines. So men glance at complex modern society with its extreme forms of social control, bewildered and anxious as the sense of insecurity mounts alarmingly.

Has organized life become so complex that it is getting out of hand?

Totalitarianism strides upon the scene and offers to compose the troubles of the bewildered man. It assures him that he does not have to find an answer through hard personal striving and thought. He can become a mystic and deceive himself that he helps create a new and beautiful social order when what he really does is to destroy personal character and integrity — the foundation of all lasting creations. The second law of totalitarianism, whatever its brand, is to destroy individual worth and identity. Civilization needs many-faceted manhood while totalitarianism begins by destroying manhood. That each man is unique is "the central fact and miracle of creation and the denial of it is the central blasphemy". The third law of totalitarianism is to destroy, through falsehood, faith in the leadership of any opposition. Conscience is one of the special targets of totalitarianism. Permit men to exercise it and they will question and criticize government. Destroy it and they will respond to personal selfishness and commit outrages willingly in the name of a social idea.

We have seen most of Europe corroded by this doctrine and these techniques. Yet all about us is in America a passionate questioning about civilization, our American civilization, its ends and means. On this occasion I therefore choose to talk mainly about civilization rather than science.

This is possible for there are a few places in the world where men of former times thought they had found civilization and spoke in terms that we use today. In none of them did science play more than a minor role. The Greek examples are well known. I cite, rather, the history of Italy in the 14th and 15th centuries, a time nearer our own yet well before the dawn of geographical discovery and ensuing world trade — centuries before the modern scientific age. Civilization as word and idea also became popular in France about a generation before the French Revolution. This, too, was before the modern scientific age.

In these times and regions civilization meant good spirit, applied conscience, fairness interpreted by incorruptible courts, beauty, tact, good manners, the social expression of the virtues of men. It did not mean blind power, or power cunningly contrived to keep men bound to a system of work and government that makes the individual the subservient tool of ruffians at the top. Nor did it mean what it means to so many Americans — money, power, the mechanisms of applied science, "efficiency".

Yet it is no service to useful political thinking to make vast dreams of brotherhood the basis of policy and ignore the existence of power which science and engineering have extended to Protean dimensions. We might as well ignore gravity as to ignore the realities of power in international politics. On the wide horizons of human conflict today one sees the meeting of irreconcilable ideologies. Clear before us are the growing opportunities for that disintegration of personality and society which totalitarianism effects before democratic integration has begun.

Before us is the profoundly important fact that only two great powers have the opportunity to continue in the world's pioneering stage of scientific, industrial, and trade expansion. They are Russia and the United States. Every coming event in the international political field will be colored by this fact. Only these two have the vast deeps of undeveloped resources, the population growths, the technical passion, and the majestic outlook that numbers and power imply and that make them the successors of the British Empire.

While America is now in the lead, there is little to choose between the United States and Russia as to future power if we balance factors one by one — with a single exception. The Soviet system is not designed to draw out fully the individual aptitudes of men or their ultimate loyalties. The effect of this upon concerted effort, mass production, and the endlessly fruitful improvisations and experiments that take place where there is the free play of thought and effort, is yet to be determined.

When the story is told and the balance struck — it is *faith* in the progress of man, in the ulti-

mate triumph of humanitarianism that sustains effort. Not the neutron but the social impact is important. A man is a humane composition, a balance of spiritual forces — not solely a devising creature with a thunderbolt in his hands. Totalitarianism has heightened our appreciation of the spirit, for totalitarianism attacks the very citadel of personality — it rejects standards, pulls down character, avowedly and explicitly confuses issues, destroys faith in the individual.

It is time for America to shout *its* faith until every corner of the world has heard!

Ethics of Science

By Archibald V. Hill
Foreign Secretary, The Royal Society

SOME 1700 years ago there crystallized out, from many centuries of experience of the ethical necessities of medicine, the so-called Hippocratic oath. May I quote a few sentences of it:

> "The regimen I adopt shall be for the benefit of my patients according to my ability and judgment, and not for their hurt or any wrong. I will give no deadly drugs to any, though it be asked of me, nor will I counsel such. . . . Whatsoever house I enter, there will I go for the benefit of the sick, refraining from all wrongdoing or corruption, and especially from any act of seduction. . . . Whatsoever things I see or hear concerning the life of men, in my attendance on the sick or even apart therefrom, which ought not to be noised abroad I will keep silence thereon, counting such things to be as sacred secrets. Pure and holy will I keep my life and my art."

Of Hippocrates himself, who lived hundreds of years earlier, we know little for certain but this is what a modern historian writes of him:

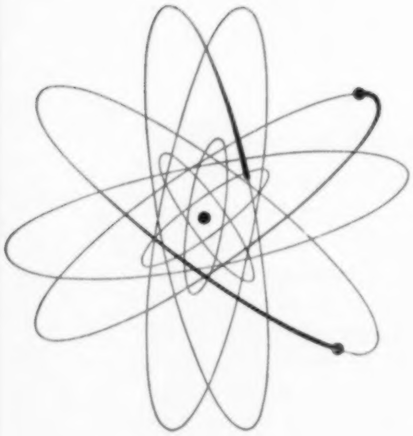
> "Learned, observant, humane, with a profound reverence for the claims of his patients, but possessed of an overmastering desire that his experience should benefit others; orderly and calm, anxious to record his knowledge for the use of his brother physicians and for relief of suffering; grave, thoughtful and reticent; clear of mind and master of his passions." Then he adds: "While the philosophers developed the conception of a rational world, it was the physician, typified by Hippocrates, who first put it to the test of experience. It was they, the physicians, who first consciously adopted the scientific process which, in relation to medicine, is called the Hippocratic Method."

The care of the sick and injured, of mothers and children, of the aged and powerless; the sanctity of human life; the insistent claim of suffering and danger — these are part of the ethical tradition of medicine. Its practitioners may sometimes fail to live up to the moral responsibility of their calling, but at least such failure is regarded as dishonorable, and the place of the doctor in society shows how generally and widely his obligation of humanity is fulfilled. It is hard indeed to imagine any kind of civilization without an *ethical* basis to medicine, without the imperatives and restraints of medical custom and tradition. Medicine in fact has been built up for thousands of years on a joint tradition of moral obligation (the Hippocratic oath) and of scientific method (the Hippocratic method).

The other sciences lag many centuries behind medicine in the ethical approach of their practitioners to their job. Perhaps that may be because science in the past was practiced chiefly for its own sake as an intellectual interest, not as a vocation of practical and social value to mankind. It had, however, its own obligations of truthfulness and integrity, and there was a time when science and learning were accepted by civilized men as a natural bond between nations often not otherwise on speaking terms. That might still be so if scientists in all countries would (or perhaps if they could) insist on collaborating, and on maintaining a common ethical standard for their calling. Failing that, one can foresee the time — if it be not on us already — when scientific discovery and invention may provide instead one of the chief stumbling blocks to international cooperation and the chief means for mutual destruction.

If standards of truthfulness, frankness and integrity are relaxed by scientists and engineers either for political motives or for private ambition and gain; if fraud, dishonesty and self-deception are not denounced; if mistakes are not honestly acknowledged and corrected; if propaganda is accepted in place of fact; if the common prestige and goodwill of science are prostituted for base, sectional or selfish purposes; if secrecy or secretiveness is accepted as a normal condition of scientific work; if age, prestige or authority, if race or nationality, is allowed to hinder freedom of intercourse between scientists of honesty and goodwill anywhere in the world; if scientists allow themselves to be conscripted for purposes of power politics; if finally there is widespread failure to recognize an unbreakable obligation that the benefits of scientific discovery must be regarded as a sacred trust for *all* mankind — *then* science itself may become impossible as a vocation for free, honest and decent men, while its exploitation for sectional gain or national aggrandizement may lead to conflict and destruction instead of cooperation and betterment.

It took hundreds of years for a common



standard of medical ethics to emerge; we can hardly expect a common standard of scientific ethics to appear overnight. All kinds of difficulties will be evident — partly from political barriers and lack of freedom; partly from scientists themselves who are, many of them I confess, pretty peculiar animals to steer in a common direction; but not least from the big bosses in all countries who look upon science as a purchasable commodity and scientists as "back-room boys" to be kept in their proper place.

But the matter is urgent and these are critical times, and a clear and unambiguous statement of the issue may help, as it helps in any scientific problem, towards its solution.

There is no suggestion, at least I make none, that scientific men as such need feel obliged to spend their time in politics; indeed it is better to refrain from mixing questions of scientific ethics with political ideologies. Scientists have their own specific contribution to make to public and international welfare, and their experience in natural science gives them no special authority to pronounce on other subjects. Indeed a dislike of misrepresentation and of compromise with the truth makes them usually pretty inefficient politicians! Like other citizens they have their political rights and social duties, but those they exercise not as scientists but as citizens.

As scientists, however, they *have* the right, and indeed the bounden duty, to question and argue the nature of their own calling and its special contribution — and its danger — to national and international welfare. They *should* feel an honorable obligation to keep the scientific faith of frankness, honesty, courage and sincerity; to avoid secrecy and secretiveness as conditions of their work; to treat all honest scientific men anywhere as coworkers in a common cause; not to exploit the common property of science for base or selfish ends; to refuse conditions of employment or advancement, however otherwise attractive, which do not meet the ethical requirements of what ought to be one of the most important common interests of mankind. I would add a further duty, one of the most important and one about which many scientific men today feel very strongly, namely, to refuse to cooperate at all in tasks in which they are not allowed a reasonable share in deciding the purpose, or the policy, or the probable outcome of their work. As free men we must be unwilling to be used as pawns in the game of international power politics, to consent in advance to the prostitution of science for secret purposes we may not approve.

To a cynical observer of the recent behavior of *homo sapiens* these moral reflections may sound naive — and I admit that I often feel skeptical myself about the outcome. But there seems to be no alternative. We scientists throughout the world must take the initiative in these matters and not leave it to others who will certainly do nothing about it. Otherwise we and civilization may perish together.

But people say, "What's the good of all these moral reflections? Admitting the emergency, what positive action do you propose?"

It has long been known that people cannot be made good or happy by Act of Parliament alone — positive individual effort and positive morality are required. I doubt indeed whether any action would be so effective now as merely to insist, day in, day out, that scientific men throughout the world should take solemn council with their consciences, in private and in public, about this matter. Of the result in any individual case one cannot be sure, and the scientific conscience itself would be outraged by a suggestion that all should be compelled to think alike — even if that were possible. But I have little doubt that the opinion of the great majority would, within rather narrow limits, be about the same, for science is the most international of all interests, with a common tradition of freedom and tolerance, a common regard for honesty and fair dealing, a common skepticism of established authority, a common independence of spirit, a common dislike of propaganda, a common conviction of the absolute goodness and beauty of truth.

The times are urgent and the world situation brooks no delay! What is needed above all else is the inspiration of a great ideal, a common international interest, a common standard of ethical behavior, a common refusal to sacrifice or exploit a universal good for a temporary or sectional advantage. We must have courage and endurance in refraining from selling reason to the forces of unreason. Those who fancy themselves as hard-boiled realists (as the "practical men" who practice the errors of their forefathers) may deride us and our principles. But the truest form of realism today is to recognize that human well-being, indeed the continued existence of human society, and any hope of reaching the promised land of healthy, orderly development, depend far more on improvements of morality, honesty, tolerance and reasonableness than on further inventions of machinery or organization.

Personals

CLINTON R. HILLIKER is now foundry metallurgist for the Amsco Division of the American Brake Shoe Co. in Chicago Heights, Ill.

EDWARD A. LORIA, formerly with the Carnegie-Illinois Steel Corp., is now industrial fellow, Mellon Institute of Industrial Research, Pittsburgh.

C. R. BASTON, JR., has recently been reaffiliated with the metallurgical department of the Steel and Tube Division of Timken Roller Bearing Co., Canton, Ohio, after 45 months in the United States Navy as assistant to the naval inspector of ordnance at the Midvale Co., Philadelphia.

ROBERT H. LACE is now quality control manager of Ditto, Inc., of Chicago. He formerly held a similar position with Lear, Inc., Piqua, Ohio.

MANUEL B. DELL is process and materials engineer with Republic Aviation, Farmingdale, N. Y.

Following his discharge from the Army, ROBERT FLAHERTY has accepted the position of design engineer for Miller Printing Machinery Co., Pittsburgh.

After 3½ years with the U. S. Navy, R. R. HERSHEY has returned to the Steel and Tube Division of Timken Roller Bearing Co. as alloy steel sales engineer in the Milwaukee district.

Crucible Steel Co. of America announces that GEORGE W. STAMM, formerly service engineer of the toolsteel sales division in Syracuse, N. Y., has been appointed assistant manager of the Cleveland branch.

R. J. BASKERVILLE, formerly with the General Electric Co., is now mechanical engineer, A. B. Chance Co., Centralia, Mo.

D. I. BROWN has resigned as contact metallurgist, alloy bureau, Pittsburgh district, Carnegie-Illinois Steel Corp., to become Chicago editor of *Iron Age*.

HUDSON T. MORTON, for 21 years chief metallurgist and sales engineer for Hoover Ball & Bearing Co., Ann Arbor, Mich., and since last September engineer for Precision Parts Co., Ann Arbor, is now standards engineer for Fafnir Bearing Co., New Britain, Conn., where he will have charge of coordinating engineering standards.

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Lubrication Engineer's Report

We knew from certain operating conditions on a Landis automatic threading machine at a prospect's plant* that we could do a better job with Chillo No. 3 than was being done with a competitive product having approximately 14% lard and 1% sulphur compound.

"The operation being performed was threading 14 to 16 foot bar stock from all grades of materials as to hardness and all sizes from ½ inch to 2 inches. On 16 foot bars of 1 inch, 1¼ inches and 1½ inches dimensions the average output was four bars of 64 feet per chaser grind with the 14% lard and 1% sulphur compound oil, and on under one inch bars the average output was 6 bars or 96 feet. The average speed or RPM while threading was 50 to 64 on the one inch and over, while the average on the under one inch was 64 to 84, depending on the hardness of the metal.

Tool Life Increased

"Although the threads were good and acceptable with the oil in use, we produced a much more uniform and smoother thread with Cities Service Chillo No. 3. We increased the tool life from four bars on the one inch and over to six and sometimes seven or an average of 100 feet per chaser grind. The under one inch production per chaser grind was increased to nine bars or approximately 140 feet.

Production Stepped Up

"We stepped up production by increasing the RPM on the under one inch bars to 84, 90, or 106, depending on the hardness, and increased the larger stock bars to 64 and 84 RPM.

"We were requested to supply a transparent oil that would not leave stains on the finished product. With this in mind and knowing that the

plant would be very critical should some work become stained, we recommended Chillo No. 3 for the job with very gratifying results."

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*Name on request.

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Personals

WALTER H. KRUPP has recently established himself as a consulting engineer in St. Louis, Mo., and is currently working in design and research on special production and processing machinery.

Chester Electric Steel Co. announces the appointment of CARL DE LAVAL as sales representative for the Pittsburgh district.

The Distinguished Civilian Service Award of the Navy Department was recently given to DONALD L. COLWELL for "outstanding achievement while serving as chief of the Conservation Division of the Production Branch, Office of Procurement and Material".

STUART O. FIEDLER has been appointed manager of the South Chicago Branch of the Bjorksten Laboratories. He was previously a research associate with this organization.

WALTER E. KINGSTON, manager of metallurgical research and development engineering of Sylvania Electric Products, Inc., has recently returned from a trip to the United Kingdom and the Continent, where he acted as a metallurgical consultant for the British Ministry of Aircraft Production.

THEODORE HESKE, formerly plant manager of Summerill Tubing Co., is now vice-president and general manager of the newly organized Ellwood Ivins Steel Tube Works, Inc., Philadelphia.

The newly organized Charles Hardy, Inc., announces the following officers: JOHN D. DALE, president; F. H. MULLIGAN, vice-president in charge of sales; J. J. CORDIANO, vice-president of research and development; CHARLES J. HARDY, assistant treasurer.

CARTER C. HIGGINS has been given the position of vice-president in charge of public relations, industrial relations, and labor relations of the Worcester Pressed Steel Co., Worcester, Mass. He was formerly vice-president in charge of sales.

"In appreciation of his enthusiastic and patriotic accomplishments as head of the Foundry Equipment Section, War Production Board" BRADLEY STOUGHTON was given a handworked tribute by the Foundry Equipment Manufacturers Association.


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GREATER CORROSION
RESISTANCE . . .
. . . because they've
been Quick-Dipped
in IRIDITE!
Maytag

Personals

E. W. SCHOEN has given up his consulting metallurgical engineering practice to join the Bellevue Industrial Furnace Co. of Detroit as metallurgical engineer.

NORMAN P. PINTO, formerly at the metallurgical laboratory of the University of Chicago, has joined the staff of the Joslyn Manufacturing and Supply Co., Fort Wayne, Ind.

After severing his connection with the Wright Aeronautical Corp., RAY A. SIMPSON has joined the Douglas Aircraft Co., Santa Monica, Calif., as metallurgist in the process engineering department.

M. K. KAHLER has left the Rustless Iron and Steel Division to accept a similar position in steel sales with the Charles G. Stevens Co., Chicago.

WILFRED E. KINREAD, formerly metallurgist with Auto Specialties Manufacturing Co., has joined the Whiting Corp. (Canada), Ltd., Toronto, Canada, as sales engineer.

EDWARD CARLETON HOOD has established himself as a consulting research engineer in Chicago.

NORMAN L. BENNETT has taken the position of metallurgist at the Verity Works of Massey-Harris Co., Ltd., Brantford, Ont.

FRANK DONICK has started his own foundry under the name of Dexter Alloys in Everett, Mass. He was formerly employed as chief engineer and metallurgist at Castalloy Co., Cambridge, Mass.

W. C. DYER has joined the Columbia Steel Co. of Torrance, Calif., with position as assistant works metallurgist.

LAURENCE W. COLLINS, JR., has affiliated himself with Oakite Products, New York City, having left Fafnir Bearing Co.

After being discharged from the Army, JAMES R. MCGUFFEY has joined the Carbide and Carbon Chemical Corp. at Oak Ridge, Tenn.

E. J. WATSON has opened an office, Watson Industrial Equipment Sales, as manufacturer's agent handling heat transfer equipment in Chicago. He was formerly chemical engineer in the research and development department of the Champion Paper & Fibre Co., Hamilton, Ohio.

Fatigue Strength of Butt Welds★

FATIGUE TESTS with the maximum stress compressive were made on butt welds in ordinary bridge steel, since weld stresses based on fatigue tests with the maximum stress tensile would probably be wasteful in such applications. The following "dependable" fatigue strengths may be anticipated in butt welds in ⅞-in. carbon steel plate with 0.25% carbon max. and 0.70% manganese max. In the tabulation C means maximum compression, T means tension stress.

STRESS CYCLE	N = 100,000 CYCLES	N = 2,000,000 CYCLES
0 to C	49,500 psi.	33,000 psi.
C to T = ¼C	27,600	18,400
C to T = ½C	20,900	14,000
C to T = ¾C	17,700	11,800
C to T = C	16,500	11,000

No tests were made to a lesser compression because the results with the zero to compression cycle show that there would be no failures except at stresses considerably over the static yield point.

Sigma Phase†

SOME HIGH ALLOY ferrous compositions are subject to embrittlement at certain elevated temperatures as the result of the formation of a constituent called sigma phase. A compilation of the findings of the most important papers on this subject indicates that certain of its characteristics have been reliably established.

In the binary iron-chromium system, sigma appears to be the intermetallic compound FeCr. Pure sigma is found from 44 to 50% chromium while the alpha + sigma field may extend as low as 26% chromium and as high as 71%. (All percentages given are in atoms per cent.) Sigma is formed from alpha at temperatures below about 1510°F., but the transformation is so sluggish that it is difficult to determine the exact limits of (To page 1226)

★Abstracted from "Fatigue Strength of Butt Welds in Ordinary Bridge Steel — Maximum Stress Compressive". Supplement No. 1 to Report No. 3 of the Committee on Fatigue Testing (Structural) of the Welding Research Council of the Engineering Foundation.

†Abstracted from "The Sigma Phase", by Francis B. Foley. *Alloy Casting Bulletin*, No. 5, July 1945, p. 1-8.

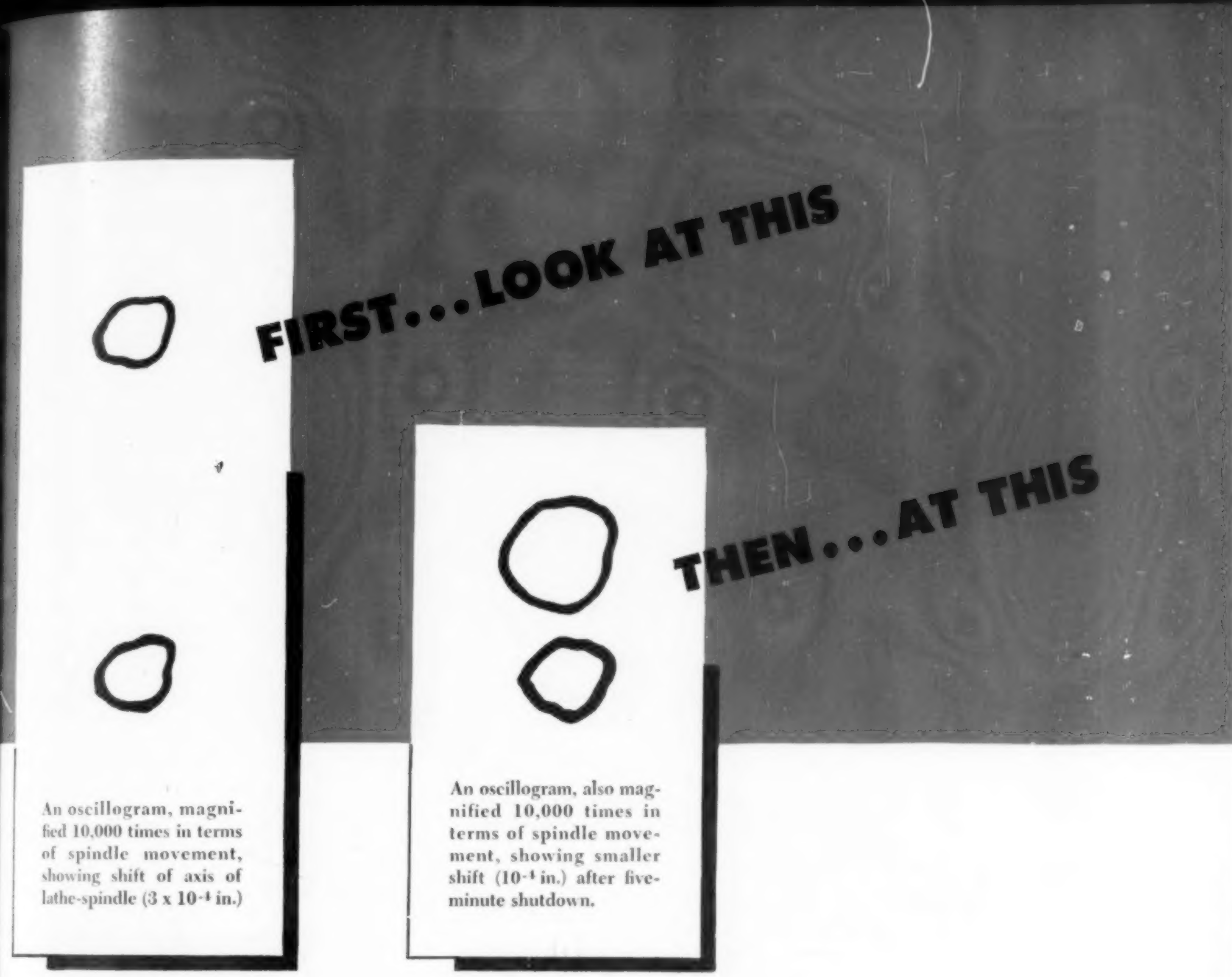
Sigma Phase

(From page 1224) composition and temperature. At temperatures over 1510° F., the sigma transforms to alpha. Sigma is a hard, brittle, non-magnetic phase with a complex, body-centered cubic lattice structure.

Sigma is also found in ternary systems, where it may contain other alloys, such as silicon, nickel and manganese, which apparently replace part of the iron. In the iron-chromium-nickel system, sigma phase persists at temperatures up to 1690° F. Its composition limits are extended and it is able to exist in equilibrium with gamma as well as alpha. With at least 3% nickel, sigma may be present in alloys with 29 to 95% chromium. In the iron-chromium-manganese system, sigma is found in alloys containing as little as 15% chromium if the manganese is 17% or higher. Manganese greatly accelerates the ferrite-sigma transformation. Silicon also accelerates the formation of sigma from the alpha phase. In the iron-chromium-silicon system, sigma may occur with only 15.6% chromium if the silicon is 14.5%. The addition of carbon to this system easily changes these limits since it removes chromium from the matrix by the formation of carbides.

In commercial alloys of the 18-8 type, the range of composition in which sigma is a stable phase is extended if the molybdenum content is increased from 1 to over 3%. It has been reported that sigma is found in an alloy with only 16% chromium, 12% nickel and 3% molybdenum. It has also been stated that sigma may form from a fully austenitic chromium-nickel-molybdenum alloy. Columbium additions tend to aid the formation of sigma somewhat.

Of four typical commercial chromium-nickel alloys, 18-8, 25-12, 25-20 and 15-35, only the latter is completely within the gamma range. The other three either fall within or very close to areas where sigma is stable. Slight additions of sigma-promoting elements such as molybdenum, silicon or aluminum can easily cause sigma to form. In 25-12 alloys with the usual carbon, manganese and silicon contents, the ratio $\frac{\%\,Cr - 16\%\,C}{\%\,Ni}$ must be under 1.7 for a stable austenitic alloy. Silicon over 1% is three times and molybdenum four times as effective as chromium in promoting the formation of sigma. *(To page 1228)*



An oscillogram, magnified 10,000 times in terms of spindle movement, showing shift of axis of lathe-spindle (3×10^{-4} in.)

An oscillogram, also magnified 10,000 times in terms of spindle movement, showing smaller shift (10^{-4} in.) after five-minute shutdown.

These Photographic Recordings, by showing effects of shutdown on lathe-spindle accuracy, helped produce precision parts in quantity.

The problem was the mass production of small precision parts on a lathe to exceptionally close tolerances...and tolerances were not being met...

Test apparatus employing an electronic circuit in conjunction with photographic recording equipment was set up to study the performance of lathe-spindles. It proved, as shown above, that the longer the shutdown, the greater the shift of spindle axis . . .

Immediate product improvement...with a lower rejection rate . . . was achieved through this investigation. And this was just the beginning – further study of additional oscillograph traces revealed other irregularities in spindle performance which led to improvements in design.

This is only *one* way in which Kodak photographic equipment, film, and paper are helping solve problems in engineering, design, production, research. For information on photographic recording materials write for the new booklet, "Kodak Materials for the Photography of Cathode-Ray Tubes."

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Sigma Phase

(From page 1226) Aluminum also increases the amount of ferrite and therefore of sigma. Columbium and titanium aid in sigma formation because they form stable carbides, therefore leaving little carbon available for the formation of chromium carbide.

Careful magnetic analysis appears to be an excellent method of detecting sigma when its presence is in doubt. It may also be checked by X-ray crystal diffraction. If sigma is present in considerable quantities, it can be readily observed microscopically.

Effect of sigma on mechanical properties is generally harmful. If appreciable amounts of sigma are formed, the steel may lose ductility to such an extent that its usefulness may be seriously impaired. Sigma may also be a factor in determining the best temperature for the successful production of wrought products. The formation of sigma during the slow cooling of castings of large sections may result in cracking if the sigma transformation is extensive.

Endurance of Large Shafts*

IN VIEW of the lack of data on the fatigue strength of large parts, overdesigning is a danger which may result from use of theoretical stress concentration factors. To obtain a more rational basis for the design of large shafts, rotating cantilever bending fatigue tests were made on shafts having a 5¼-in. diameter portion connected to a 6 9/16-in. diameter section. The shafts were machined from normalized and tempered forgings of S.A.E. 1050 with a tensile strength of 102,000 psi. and a Brinell hardness of 197 at half-radius.

Three types of fillets connecting the two portions of the shaft were tested, namely, 11/32 in., circumferentially polished to a finish of 5 to 11 microns; 5/32 in., polished in the same way; 5/32 in., rolled with a 3⅝-in. diameter single roller burnishing tool under a pressure of 1500 lb. The rolling increased the hardness to Vickers *(To page 1230)*

*Abstracted from "Fatigue Strength of 5¼-In. Shaft as Related to Design of Large Parts", by O. J. Horger, T. V. Buckwalter and H. R. Neifert. *Journal of Applied Mechanics*, V. 12, Sept. 1945, p. A-149 to A-155.

Endurance of Large Shafts

(From page 1228) 228 for a depth of ¾ in. The following endurance limits were obtained on the basis of 30,000,000 cycles:

Fillet	Finish	Endurance	F*
27/32 in.	polished	25,500 psi.	79
9/32	polished	18,500	77
9/32	rolled	24,000	

*Actual stress concentration factor from fatigue tests as a percentage of the theoretical stress concentration factor.

A 0.3-in. polished specimen taken at 3 3/16-in. radius from the larger portion gave an endurance limit of 36,000 psi. One test indicated that apparently the shape of the roller tool was not important. In all but one failure, the crack originated at a location up the fillet from the base of 8 to 11° for the polished 27/32-in. fillet, 10 to 14° for the polished 9/32-in. fillet, and 15 to 20° for the rolled 9/32-in. fillet. There was no evidence that the fatigue crack might be initiated below the surface of the rolled fillets.

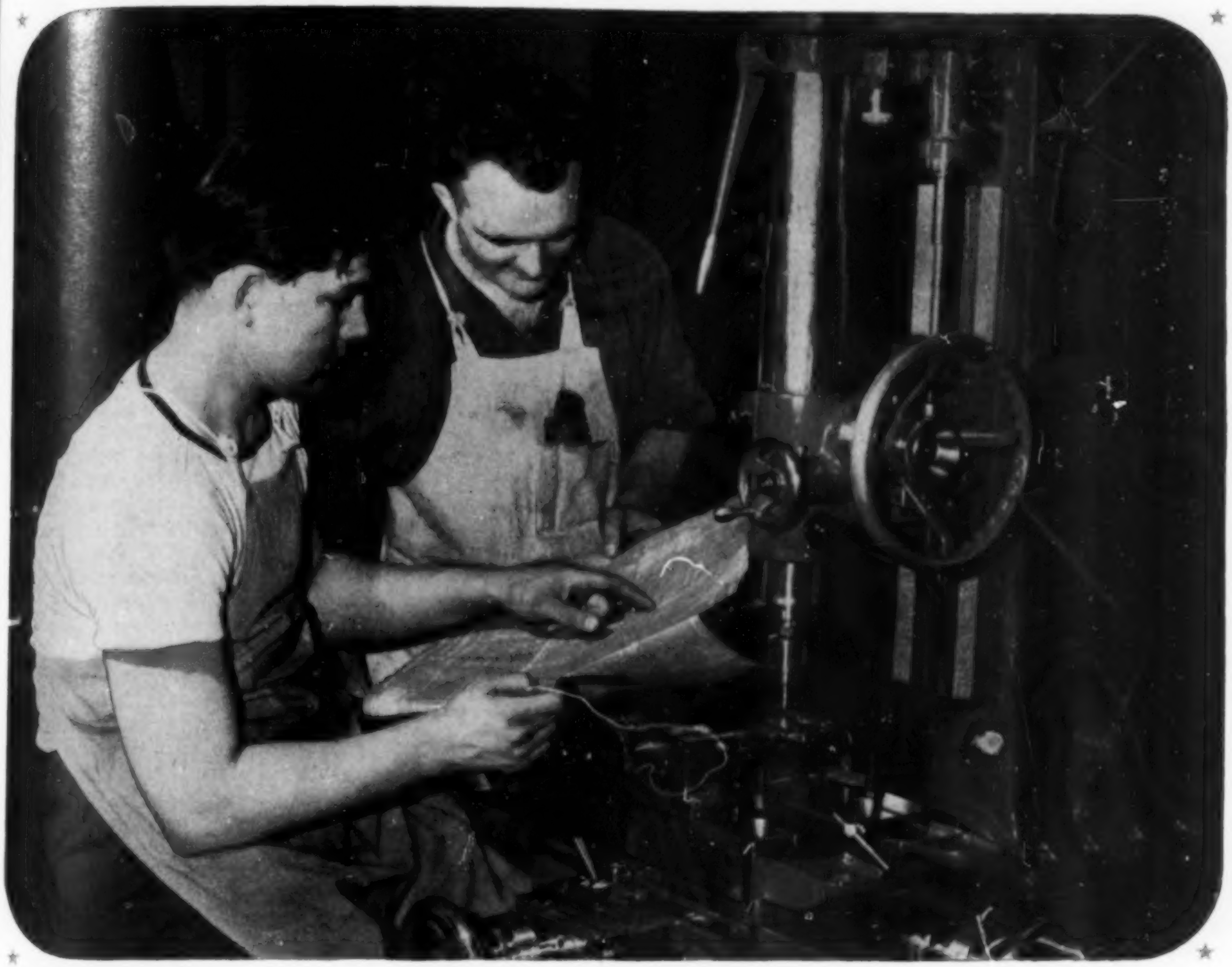
The 30% improvement resulting from rolling compared with values of 30 to 68% reported on smaller specimens.

Stabilization of Stainless Steel*

RYAN AERONAUTICAL CO. has made a series of investigations to determine whether stabilizing treatments would impart any benefits to aircraft exhaust manifolds made of Types 321 and 347 stainless steel. Originally 18-8 was used for exhaust manifolds but it was rapidly attacked by intergranular corrosion from exhaust gases. This led to the use of the stabilized Types 321 and 347.

The addition of titanium and columbium is not the only means utilized to effect stabilization; it is enhanced by special heat treatment consisting of holding at 1575 to 1625° F. for over half an hour. This treatment stabilizes the carbon by precipitating it as titanium or columbium carbides in random dispersion. There- *(To page 1232)*

*Abstracted from "Heat Treatment of Stainless Steel for Exhaust Manifolds", by Wilson G. Hubbell, *Aero Digest*, V. 50, July 1, 1945, p. 98; also *Iron Age*, June 21, 1945, p. 56.



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Stabilization of Stainless

(From page 1230) fore, no carbon is available for the formation of the harmful chromium carbides if the material is to be used within the so-called sensitizing range of about 900 to 1500° F.

The theory behind the stabilizing treatment is correct, and it may be required for resistance to corrosion in highly corrosive solutions. However, the correlation between corrosion under these conditions and resistance to the type of corrosion obtained in exhaust manifolds is not satisfactory. The titanium and columbium in Types 321 and 347 is sufficient to give adequate stabilization of the carbides for exhaust manifolds without special heat treatment.

Exhaust manifolds will resist corrosion where a combined precipitate of titanium or columbium carbides and chromium carbides exists after sensitizing. A completed exhaust manifold of Type 321 or 347 shows random titanium or columbium carbides and a dispersion of chromium carbides along the grain boundaries, spaced at such distances apart as to be no cause for concern over ultimate serviceability. There is a relationship between the time in service and the type and distribution of the carbides.

An exhaust manifold with more than normal life which failed by mechanical wear showed a microstructure with a heavy network of carbides. Yet this network did not contribute to excessive corrosion since the attack amounted only to a maximum of 0.005 in. on the inside. Sections from such a manifold will show a 20% greater loss in thickness in a copper sulphate sulphuric acid solution in 48 hr. than will be obtained under service conditions up to 4000 hr. Since there is no correlation between the accelerated corrosion tests required by the specifications and actual service, such tests are of little value.

There are two major causes of manifold failure — a fatigue failure which occurs in an open area subjected to strong pulsating forces, and failures where severe stress raisers are present in a critical area. Both may be rectified by design. No case has been found where excessive carbide precipitation or intergranular corrosion contributed to service failure.

A number of tests were made on a heat of Type 321 with 0.078% carbon and 0.376% titanium and a heat of Type 347 *(To page 1234)*

Stabilization of Stainless

(From page 1232) with 0.07% carbon and 0.88% columbium. All arc welds, both those subjected to a stabilizing heat treatment and those not so treated, had satisfactory resistance to carbide precipitation and intergranular corrosion. Sensitizing did not affect this resistance. Gas welded Type 347 had better resistance in the Strauss test than gas welded Type 321. These welds had been heated to 1650° F. for 2 to 3 min. for stress relief. The bend tests on the welded zone after the embrittlement tests required by AN-QQ-S757 proved more satisfactory than expected. All but one sample, which cracked during preparation, withstood bending 180° over a diameter equal to twice the thickness of the material. Compression failures on the inside of the bend radius were noted in all specimens.

It therefore has been concluded that a stabilizing heat treatment exerts some small but inconclusively beneficial results on Types 321 and 347 in improving resistance to attack by corrosive aqueous solutions. There appears to be no justification for assuming that any substantial and practical benefit will be obtained by applying this heat treatment to aircraft exhaust manifolds.

Apart from the metallurgical considerations, the scale formed at 1600° F. is very tight and thin and is not readily removed by the usual acid pickling. Sandblasting or special pickling must be used. It would also necessitate an increase in furnace capacity since a minimum of half an hour at temperature would be required instead of the usual 10 to 15 min. Another manufacturing problem which is not as serious from a cost standpoint is the question of warpage on the finished part.

It has long been known that the presence of precipitated carbides tends to increase the yield strength at room temperature. A few tests by other investigators indicated that at 1100° F. the creep strength is lowered 10 to 20% by the stabilizing heat treatment. These results tend to bear out the theory that a small amount of carbide precipitation along the grain boundaries and slip planes would enhance the elevated temperature strength. This may be a more important factor in determining the service life of an exhaust manifold than any actual corrosion by exhaust gases.

(Concluded on page 1236)

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Stabilization of Stainless

(*Starts on page 1230*)

The amount of chromium carbides allowable without danger of intergranular corrosion for the enhancement of the high temperature strength of the material should be determined. Factual data are lacking but are proved by the many exhaust manifolds in service which have been given no stabilizing heat treatment.

Aging of Sintered Copper Alloys*

IN THE PREPARATION of high electrical conductivity compacts, the purity of the copper powder is important as well as its density and internal stress. Electrolytic copper has proven especially suitable and was used in the present work.

The density as pressed and as sintered increased directly with the compacting pressure. Variations in the initial pressed density within the range of 5 to 6 g. per cc. affected only slightly the pressure required to obtain a given re-pressed density after sintering. For any given initial pressed density, there was a straight-line relationship between both the hardness and tensile strength and the re-pressed density. The initial pressed density before sintering and re-pressing had a drastic influence on the tensile strength, which increased materially with decreasing initial pressed density. The hardness values did not indicate the wide spread in tensile strength. The greater amount of cold working received by the samples with the lower initial density resulted in a higher final hardness when re-pressed to identical densities.

The material with the lowest initial (pressed) density had the lowest electrical conductivity, probably because of the greater amount of cold work necessary to re-press it to a given structure. The choice of the initial pressed density will be governed in practice primarily by the physical (*To page 1238*)

*Abstracted from "Notes on Copper-Base Compacts and Certain Compositions Susceptible to Precipitation Hardening", by F. R. Hensel, E. I. Larsen and E. F. Swazy. American Institute of Mining and Metallurgical Engineers Tech. Pub. No. 1810, *Metals Technology*, Aug. 1945, 12 p.

Aging of Copper Alloys

(Continued from page 1236)

properties concomitant with the initial pressed density.

The optimum density and hardness values on hot pressing were obtained with a pressing temperature of 750° F. There was an increase in density with compacting temperature. The hardness values were higher than could be obtained in cold worked wrought copper. The annealing temperature of the hot pressed copper compacts was higher than that of cold worked commercially pure copper. Although hot pressing gives physical properties that cannot be obtained in any other way, it is seriously handicapped by early die failure.

A series of compositions with additions of nickel, phosphorus, manganese, chromium, tin, cobalt, silicon, and titanium hydride was investigated. It was necessary to carry out all the high temperature heating operations in hydrogen since the alloys would not respond properly to the precipitation treatments if the sintering or solution treatment were conducted in air. Tensile data were determined only on the more promising alloys.

Manganese-phosphorus and nickel-tin additions did not produce appreciable precipitation hardening. Promising results were obtained with nickel-phosphorus, chromium, cobalt-phosphorus, nickel-beryllium and cobalt-beryllium additions. Age hardenable alloys with chromium, cobalt-beryllium or nickel-beryllium had excellent physical and electrical properties. The addition of small amounts of phosphorus or titanium hydride was beneficial. The titanium hydride apparently produced a cleaner material relatively free from oxidation.

The highest tensile strength (78,200 psi.) with an electrical conductivity of 41% (of international standard) was found in an alloy with 2.5% cobalt and 0.5% beryllium. The equivalent nickel-beryllium alloy had a tensile strength of only 52,000 psi. but an electrical conductivity of 61%. An alloy with 3% chromium, 0.1% phosphorus and 0.5% titanium hydride had a tensile strength of 52,000 psi. with an electrical conductivity of 69.1% I.A.C.S.

The precipitation hardening depended upon the solution of the alloying element in the copper matrix; time, *(To page 1240)*

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Aging of Copper Alloys

(From p.1238) temperature, particle size and type of particle were contributing factors. The aging characteristics were not radically different from those of wrought alloys but the sintered alloys had a decreased tendency toward overaging. The alloys with beryllium were susceptible to the formation of a soft skin caused by the partial oxidation of the beryllium. The addition of 0.2 to 0.3% phosphorus greatly reduced or retarded the formation of the soft shell and did not adversely affect the precipitation hardening characteristics.

New Solution for Aluminum Welding*

TESTS WERE MADE to develop a room temperature solution for preparing alclad 24S-T for spot welding. Contact resistance measurements were used to indicate the weldability of the aluminum alloy. The following solutions were felt to be unsuitable for production: 1 to 10% acetic acid + 0.05 to 0.3% ammonium bifluoride; 1% acetic acid + 0.1% sodium or ammonium fluoride; 10 to 15% sulphuric acid + 10 to 15% phosphoric acid; 1% sulphuric acid + 0.025 to 0.2% sodium fluoride; 2% hydrofluoric acid + 3.1% boric acid; 3.1% boric acid + 1% sodium fluoride + 1% oxalic acid; 1 to 15% phosphoric acid; and 0.2 to 1% hydrofluoric acid. All solutions contained an addition of wetting agent.

Many of these solutions were too critical from the standpoint of time, temperature or concentration limits. Some of them also produced a milky surface on the alloy. Moreover, a number had a severe limitation in use since there was no simple method of measuring their activity other than by contact resistance measurements. A simple titration of these mixtures would not indicate the concentration of the critical compounds. Turco and Koldweld processes had the same disadvantage. (To page 1242)

*Abstracted from "The Surface Treatment at Room Temperature of Aluminum Alloys for Spot Welding", by W. F. Hess, R. A. Wyant and B. L. Averbach. *Welding Journal, Welding Research Supplement*, Sept. 1944, p. 417s-435s.

Aluminum Welding

(Continued from page 1240)

Kelite K-1 was capable of treating aluminum surfaces at room temperature, while several of the acid plus fluoride salt combinations could be used if surface resistance measurements were used for control purposes. A 15% solution of phosphoric acid could also be used although it was unusually sensitive to temperature changes.

However, one very satisfactory solution was developed with hydrofluosilicic acid. The best results were obtained with a 3% by volume solution of acid with 0.1% by weight of Nacconal NR. The time varied with gage and temperature. For bath temperatures of 65 to 85° F., the time increased from 6 min. for 0.020-in. sheet to 10 min. for 0.064-in. sheet. The desirable characteristics included room temperature operation, a simple mixture, a short treatment time, low cost and no health hazard. Also, a bright smooth finish was obtained on alclad material. Rapid and precise control was possible by means of a simple titration.

This solution was successfully tried in production at one plant. Assemblies could also be treated provided the clearance between faying surfaces was sufficient to allow adequate rinsing. Recent experience has indicated that a 1.5% solution may be preferable for alclad 24S-T and some of the newer alloys such as R301T.

Air and nitrate treated alclad 24S-T responded differently to every chemical surface treatment tested. Material heat treated in air was more critical, responded more rapidly and showed erratic surface resistances. This difference was probably caused by the diffusion of copper through the cladding, as the result of the longer heating times for air treated stock. However, equally consistent welds could be produced in either type of material. The indications were that very large changes in surface resistance were necessary to alter appreciably the weld strength.

The room temperature solutions were completely unsatisfactory for the treatment of bare 24S-T. A 2% nitric acid solution at 180° F. gave uniformly low surface resistance and consistent welds in this type material. It could also be used for alclad materials if necessary.